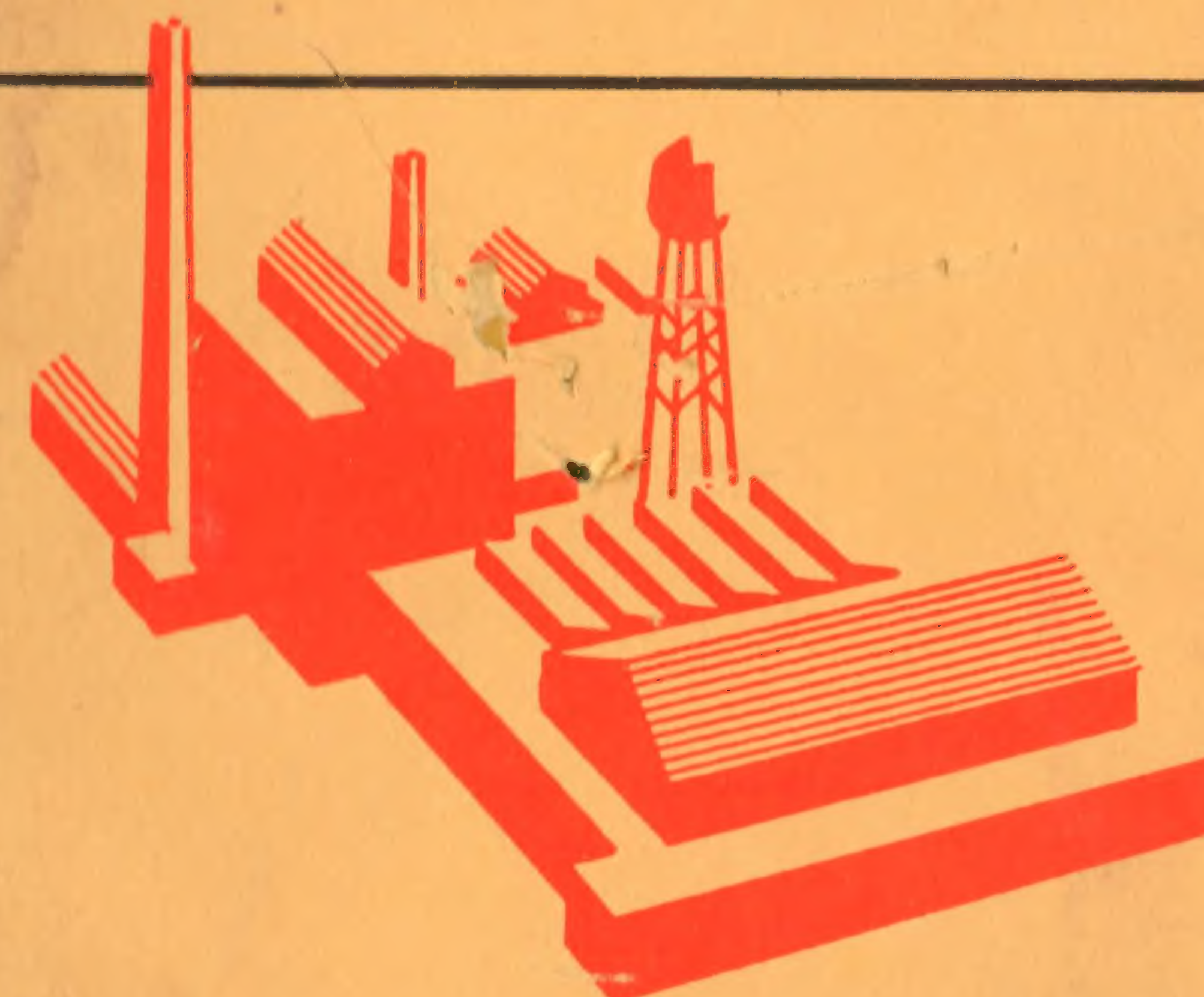
FUNDAMENTAL SHOP TRAINING

SHUMAN
MONROE
WRIGHT

AMERICAN
TECHNICAL
SOCIETY

# *Fundamental*
# SHOP TRAINING



SHUMAN ★ MONROE ★ WRIGHT

# *A Student's Creed*

I WILL blot out of my life the failures that come through wasted hours, and write into it the achievements that come through time well spent.

I will keep life's record clean, a story of knowledge gained and service given.

I will keep always in mind the high goal of our democracy, and will hold my hand to its task.

I will work hard, hope high, and live up to the best that is in me.

## *A Creed*

### FOR WORKER AND WARRIOR

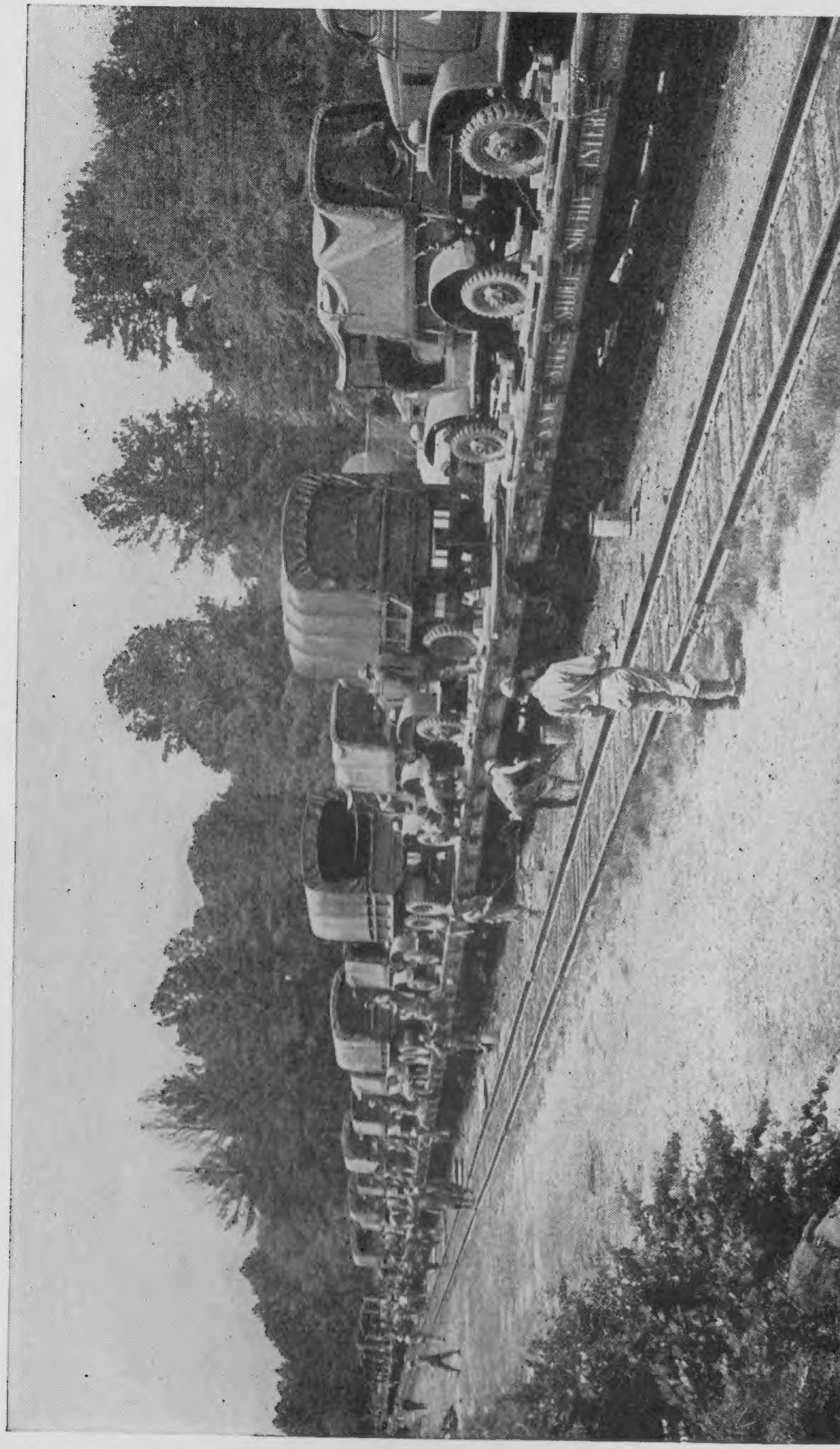
I BELIEVE in the fatherhood of God and the brotherhood of man.

I believe in the freedoms we fight to preserve.

I believe in the worth and dignity of the common man.

I believe in doing my job with intelligence and skill.

I believe in making my life and the quality of my work count toward saving those freedoms, whether in the shop, in training camps or in actual warfare against our enemies.



LOADING 2½-TON AND ½-TON TRUCKS ON RAILROAD FLAT CAR AS AN INFANTRY DIVISION PREPARES TO MOVE OUT OF FORT BENNING, GA.
*Photo by U. S. Army Signal Corps*

*Fundamental*

# SHOP TRAINING

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And a Staff of Technical Experts


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1945

**AMERICAN TECHNICAL SOCIETY**

**CHICAGO, U.S.A.**


[ILLUSTRATED]

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# INTRODUCTION

Out of every hundred men inducted into the service, according to a high-ranking Army officer, eighty-six are assigned to duties requiring specialized training. This explains the urgent need for the preinduction training courses which the War Department has called upon the schools of the nation to provide.

The modern army is a mechanized army, and its formation and development are slowed tremendously when, as at present, the large majority of men drawn into it lack even a speaking acquaintance with the tools, the processes, and the principles of operation of the equipment they must use.

Shortages in skilled man power are becoming acute, even in civilian life, and it is unlikely that the Army will induct any appreciable number of experienced men into service. Instead, it must train men in these various skills and crafts, and at the same time carry on its intensive program of physical development and of training in the actualities of combat. An army's fundamental job is to teach men to fight; it should not be necessary to take time and facilities urgently needed for this job, and devote them to the sort of training that could be given these men before induction. It is obvious that the problem of building our Army would be made easier, and the fighting efficiency of our forces would be heightened and speeded, if the thousands of young men and boys in high schools, who will ultimately be in that Army, were given short, but comprehensive, intensive courses in the fundamental technical knowledge and skills that are so urgently needed.

An untrained soldier is a hazard to himself and his fellows. The very best possible individual training means the lowest possible percentage of casualties and a war won in the shortest possible time. To this end, the schools and the publishers of textbooks for the schools have been asked to cooperate to provide a background of technical knowledge which every modern soldier needs.

To the American Technical Society, publishers of vocational textbooks, through so many years, and to other publishers in the field, has fallen the task of preparing the texts and courses for preinduction training in the fundamentals of electricity, of shop work, and of machines.

We have prepared these books so that each will present the prerequisite knowledge in its field in the simplest manner, a manner which will make both learning and teaching as easy and rapid as is humanly possible. To do this, we have prepared not only the textbook for each field, but an accompanying workbook, with laboratory and project problems, and a complete classroom study program using our own "Six-Step Plan of Training," a plan developed through many years of experience in teaching by the home study method. We have done this because we are aware that many schools are already and increasingly short-handed as to teaching staff, and because we feel that this method will, in the shortest possible time, give the student the clearest and most complete understanding of the basic principles and skills involved in each of these technical fields.

We submit these textbooks in the sincere belief that they will prove a vital factor in increasing the efficiency and skill of the individual soldier, making his service in our Army easier and bettering his chances for advancement, while at the same time his work becomes more effective and valuable. We feel that through this service to our Army we are performing, in this period, a service to our country and to the peoples of all the world.

AMERICAN TECHNICAL SOCIETY

# PREFACE

This textbook and the accompanying workbook, embody a basic course in fundamental shop skills. It follows the War Department's recommended outline and includes information necessary to operational skills essential to more than twenty Army occupations. Among these, the War Department lists jobs of automobile, airplane, engine, radio and artillery mechanic; radio, telephone, telegraph repairmen, operators and mechanics; ship or construction carpenter, or construction foreman; welder; electrician; bridge builder, or airplane armorer.

This course is designed to provide thorough and careful instruction in fundamental shop skills and techniques, to develop manipulative skills, and to impart a knowledge of the qualities and characteristics of materials, and of construction processes and procedures. It is presented by our "how-to-do-it" method—a method which makes any subject easier to learn and easier to teach. The text itself is devoted mainly to principles and methods. The workbook contains detailed instruction using the Six-Step Plan of presentation and suggests a series of elementary projects to be worked out by the student.

In preparing specialized materials for this fundamental shop training course, we have drawn from and wish to acknowledge use of material and illustrations furnished by War Department Technical Manuals TM 11-453, TM 4-315, TM 1-435, TM 1-455 and War Department Field Manuals FM 5-10 and FM 24-5, and by Sears Roebuck and Co., The Pittsburgh Plate Glass Co., and Bell Telephone Co.

The "Glossary of Shop Terms," composing Part 9, was prepared by A. C. Telford, Supervisor of Defense Training, and Anton R. Blomquist, Head of Building Construction, at the William Hood Dunwoody Industrial Institute.

Much of the material is taken from our own extensive treatments of the subjects in "Machine Shop Work," "Flight," and "Carpentry."

# CONTENTS



*Note.—For page numbers see foot of pages.



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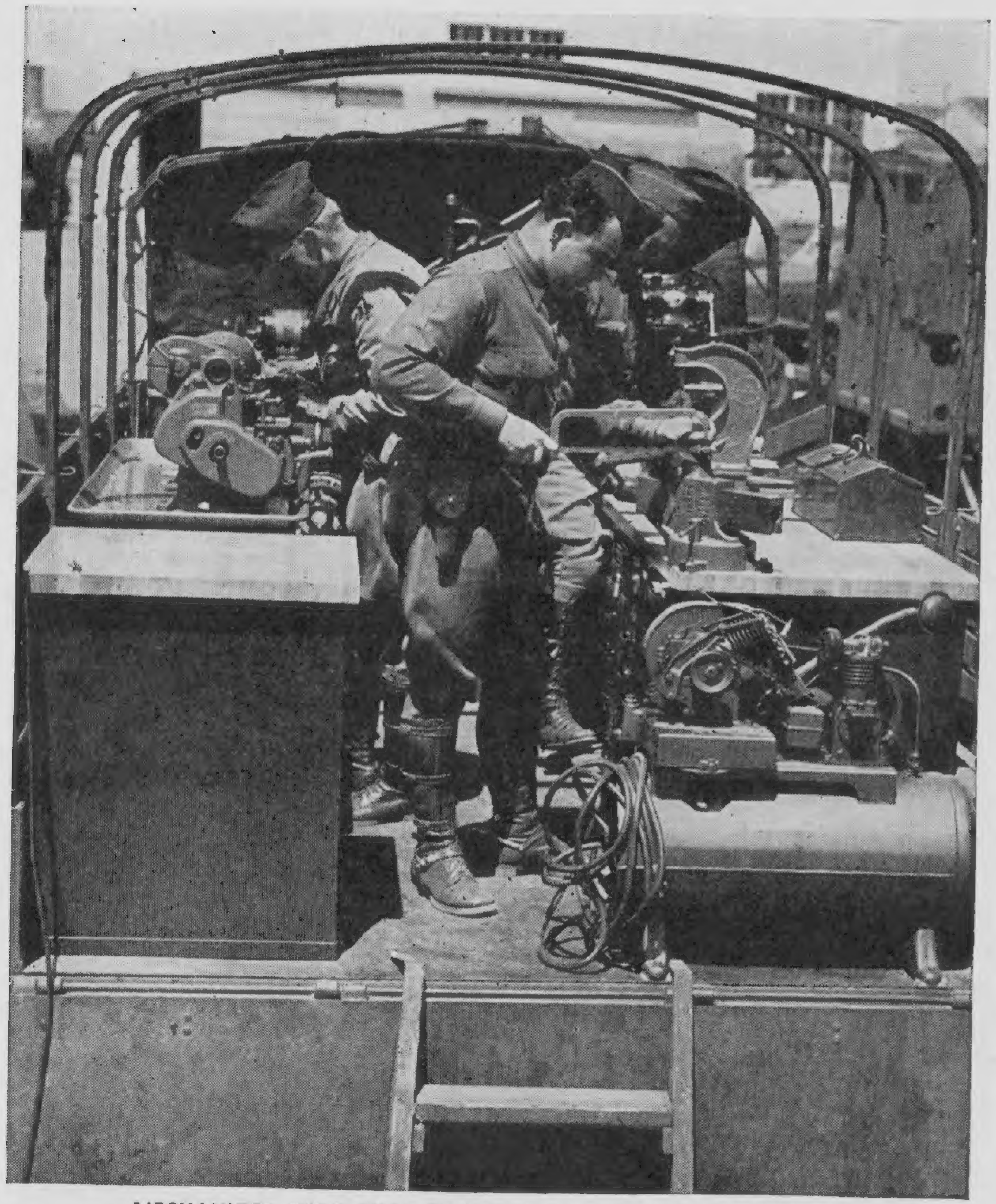


MECHANIZED FIELD SHOP TRUCK OF 107TH CAVALRY REGIMENT
*Photo by U. S. Army Signal Corps*



PART 1

# Common Hand Tools

## HAMMERS, SCREW DRIVERS, WRENCHES, ETC.

**SIMULTANEOUS USE OF HAND TOOLS AND MACHINES.** Machine shop work is usually understood to include all cold metal work in which a portion of the metal is removed, either by power-driven or hand tools, to make the piece of the required shape and size. However, there are some branches of cold metal work, such as sheet-iron work and coppersmithing, that are not usually included in machine shop work.

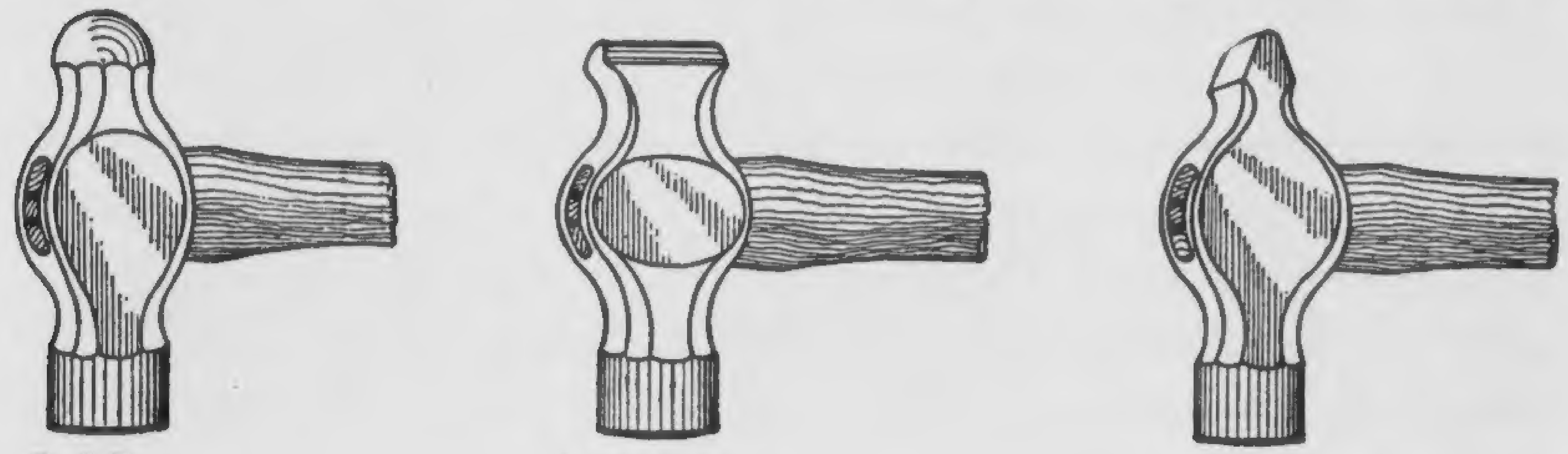
As the hand-operated tools are much simpler, and as the operations performed with them are in every case more typical, their description and use should precede that of power-driven tools. It should be clearly understood, however, that machine shop practice involves the use of both classes at the same time. Even hand tools are not used in the same order on different classes of work; it is, therefore, impossible to describe them in the order of use. Simplicity of construction and operation will be the guide for discussing the uses of various tools.

## HAMMERS

**CLASSIFICATION.** The machinist uses hammers of three shapes: ball peen, cross peen, and straight peen, Fig. 1. The ball peen is the most common; it varies in weight from 4 ounces to 3 pounds. The cross peen and straight peen hammers vary from 4 ounces to 2 pounds and are used principally in riveting. Hammers are made from a good grade of tool steel, hardened, and drawn to a blue color at the eye and a dark straw on the face and peen. The eye is elliptical in shape, and the handle is fastened by driving wedges, either wood or iron, into the end of the handle, thus spreading it to

fill the eye. The handle is of hard wood, preferably hickory, and of a length suited to the weight of the hammerhead. When the handle is properly inserted, the axis of the head stands at right angles to the axis of the handle.

**SOFT HAMMERS.** Soft hammers are used for striking heavy blows where the steel hammer would bruise the metal or mar the



Ball Peen Straight Peen Cross Peen

Fig. 1. Hammers

surface. They are made of rawhide, copper, or Babbitt metal, and vary in weight from 6 ounces to 6 pounds. They are subject to rapid wear, but are indispensable in setting up and taking down machinery.

### HOW TO USE HAMMERS

1. Make sure the head is fastened securely. If the handle is loose, drive the wedge farther into the handle. A loose hammer head is dangerous.
2. Grasp the hammer firmly near the end of the handle.
3. Start all work with light blows to get it started properly.

## SCREW DRIVERS

On tool work of various kinds flat head and fillister head screws and set screws are used. Therefore it is necessary for the toolmaker

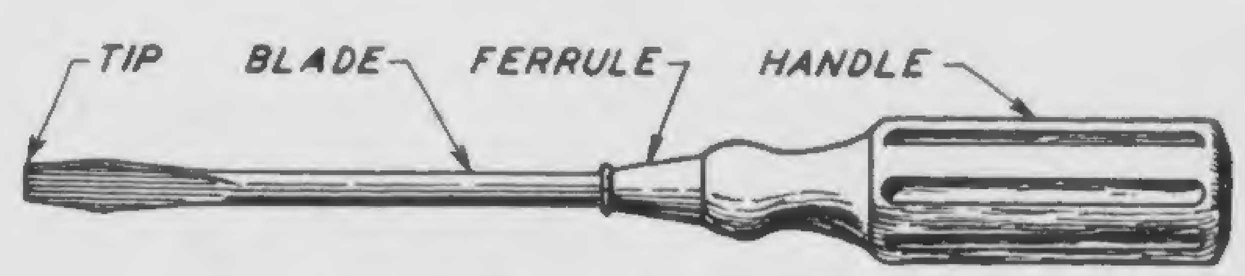



Fig. 2. Standard Screw Driver

to have one or more screw drivers to drive these screws or to remove them.

Screw drivers are made with blades of various widths, in lengths suited to special purposes. Fig. 2 shows a regular type screw driver. The blade section is made of forged carbon tool steel, heat treated





to give the hardness and toughness needed to withstand the twisting motion employed in driving a screw. Wooden handles are fastened to the blades with rivets.

The stubby ball-handle screw driver is used on jobs where there is little clearance. The handle is designed to fit the palm of the hand and to give a firm grip. With this type of screw driver it is possible to handle large size screws.

Sometimes it is necessary to make up special screw drivers for driving the largest size screws. For this purpose a piece of drill rod is used. The blade section is forged to the proper width, ground to the approximate size, then heat treated. Often a square or flat is milled on the shank so a wrench can be used for added leverage. In some cases a hole is drilled through the shank so that a steel pin or bar can be inserted to provide leverage.

**OFFSET SCREW DRIVERS.** This screw driver, Fig. 3, is made so that screws can be tightened or removed in places that would be

Fig. 3. Offset Screw Driver
*Courtesy of Goodell-Pratt Co., Greenfield, Mass.*

inaccessible to the ordinary type of screw driver. Four blades cover eight different positions of the screw slot. A turn of only ⅛ inch is required for operation.

### HOW TO USE SCREW DRIVERS

1. See that the tip of the screw driver is in good condition, the bottom squared, and the sides straight, as shown in Figs. 4 and 5.

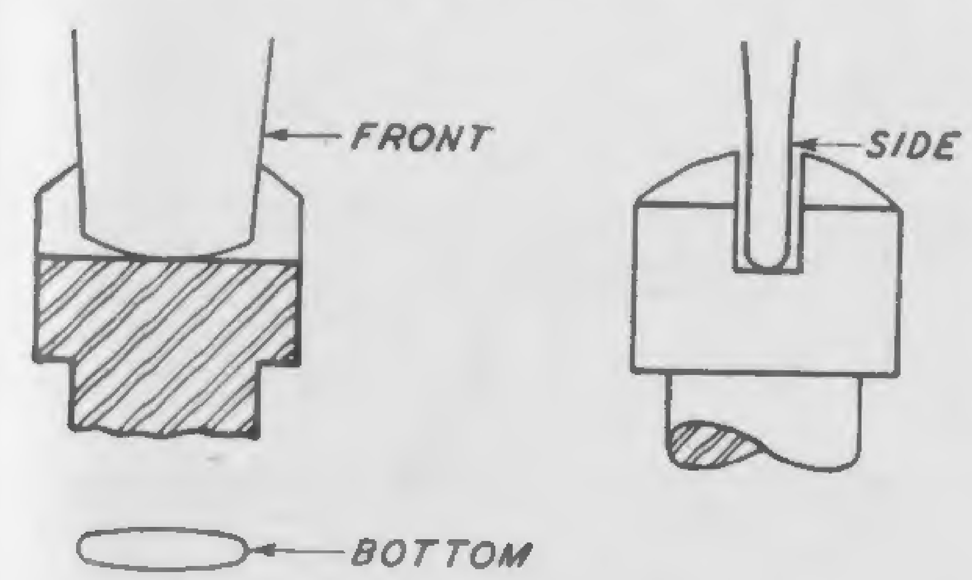



Fig. 4. Poor Screw Driver Tip

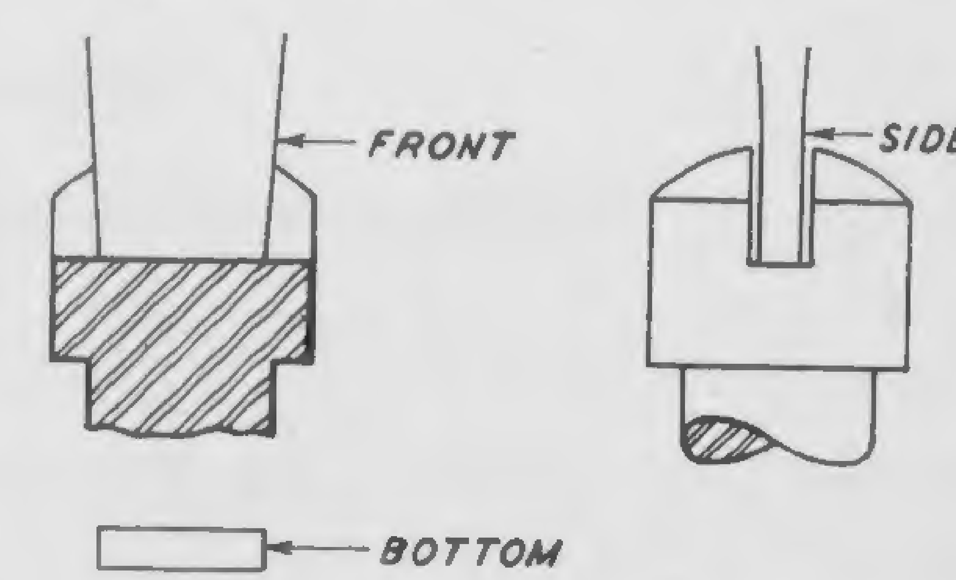



Fig. 5. Good Screw Driver Tip

2. With the right hand, grasp the handle. With the left hand, guide the tip into the screw slot, as shown in Fig. 6.

3. Tightening large screws. Use a square-shanked screw driver, and with a wrench that fits the square shank, turn the screw driver. See Fig. 7. Pressure must be kept on the handle to keep the tip in the slot.

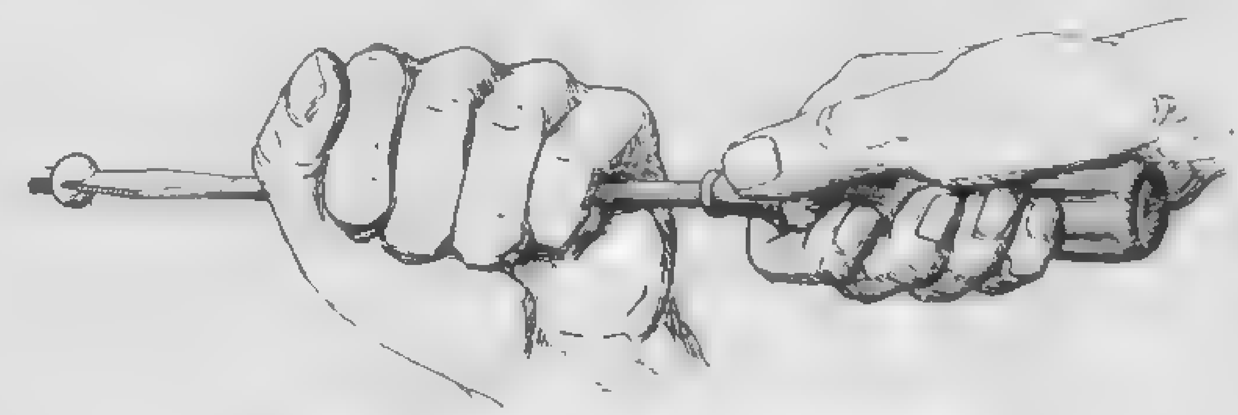


Fig. 6. Holding a Screw Driver

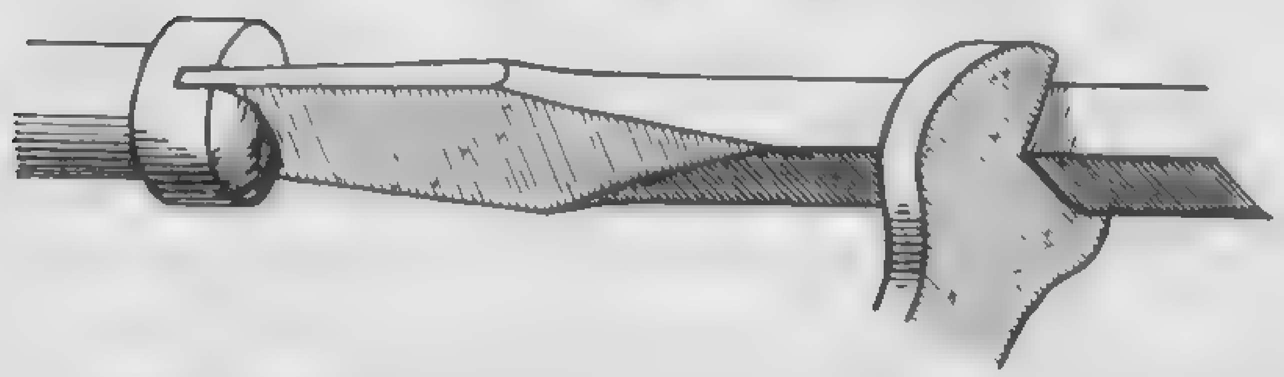


Fig. 7. Turning a Square Shank Screw Driver with an Open End Wrench

4. Do not strike the handle of the screw driver with a hard object. This will split the handle.

5. Do not use your screw driver as a wedge, or chisel.

6. Be sure that the screw driver fits the screw slot.

### QUESTIONS

1. *Why should a screw driver blade have parallel sides?*
2. *Why are screw driver blades made from carbon tool steel?*
3. *Why are the larger sizes of screw drivers frequently made with square blades?*
4. *How is a screw driver blade hardened? Why?*
5. *What is an offset screw driver?*
6. *How should a screw driver be held?*
7. *Why is it necessary to exert two different forces when using a screw driver, namely, turning force and a holding or pushing force?*
8. *What method can be used to make the tightening of large screws easier?*
9. *What might happen if the screw driver jumps out of the screw slot?*
10. *What might cause a screw driver to jump from the screw slot?*

## WRENCHES

Many different types of wrenches are made for turning nuts, bolts, pipes, etc. They usually derive their names from characteristic shapes as *S* wrench, *angle* wrench; from the object they are used to turn, as *pipe* wrench, *tap* wrench; or from their construction, as *spanner* wrench. See Fig. 8.

Whenever the correct sizes are available, the open and closed end types of wrenches are to be preferred to the adjustable wrenches.

Since the wrench is a lever. the mechanical advantage or the





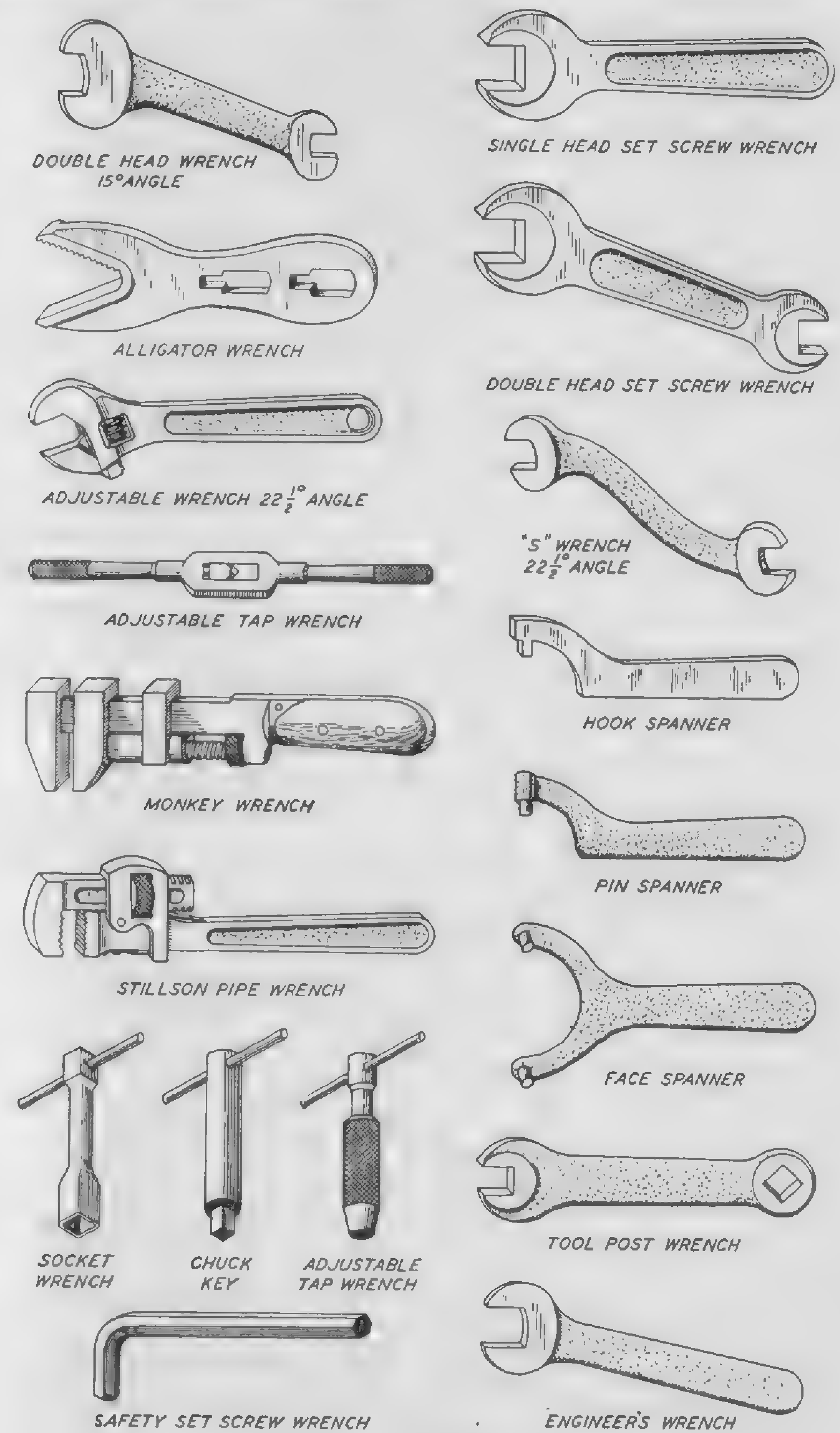



Fig. 8. Types of Wrenches

leverage secured is in proportion to the length of the handle. Usually, the handle of a solid wrench is made so that it will give all the leverage the part to be turned will probably stand. This is not so with an adjustable wrench. Hence, when a large adjustable or monkey wrench is used on a small nut or bolt, the part may be broken easily unless proper judgment is exercised.

### HOW TO USE OPEN AND CLOSED END TYPE WRENCHES

1. The wrench should fit closely, Fig. 9. A loose fitting wrench will round the corners of the bolt and slip badly, resulting in hand injuries.

2. A quick jerk, when tightening a bolt, or a blow with the ball of the hand when loosening a nut or bolt, Fig. 10, is often more effective than a steady pull.

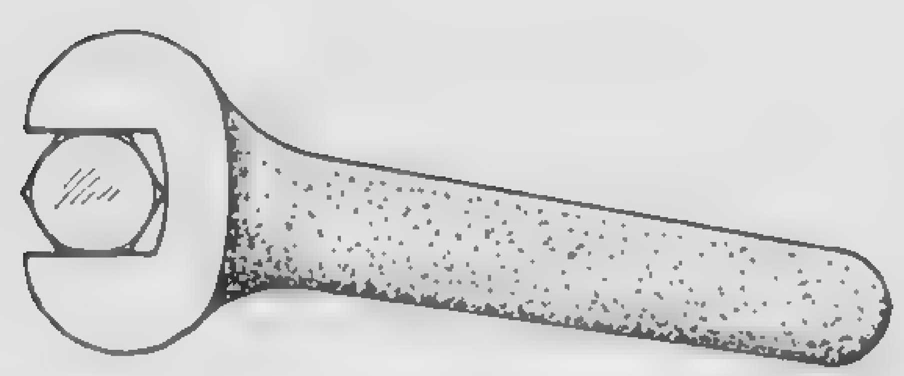


Fig. 9. Wrench Making a Good Fit

Fig. 10. Slight Bumping with Hand

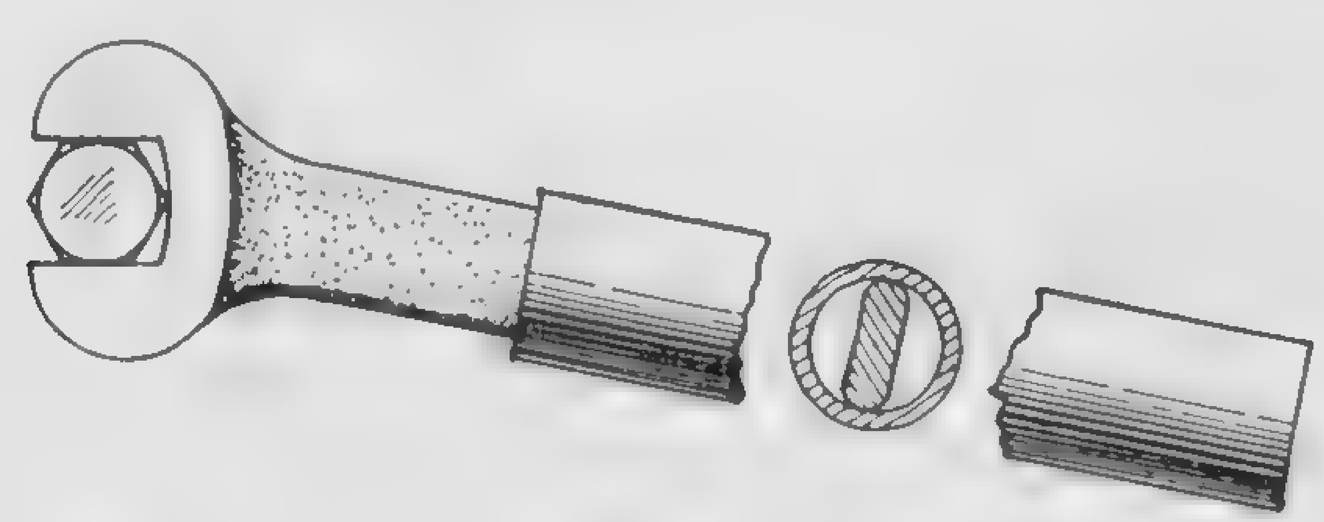


Fig. 11. Wrench with a Section of Pipe on the Handle

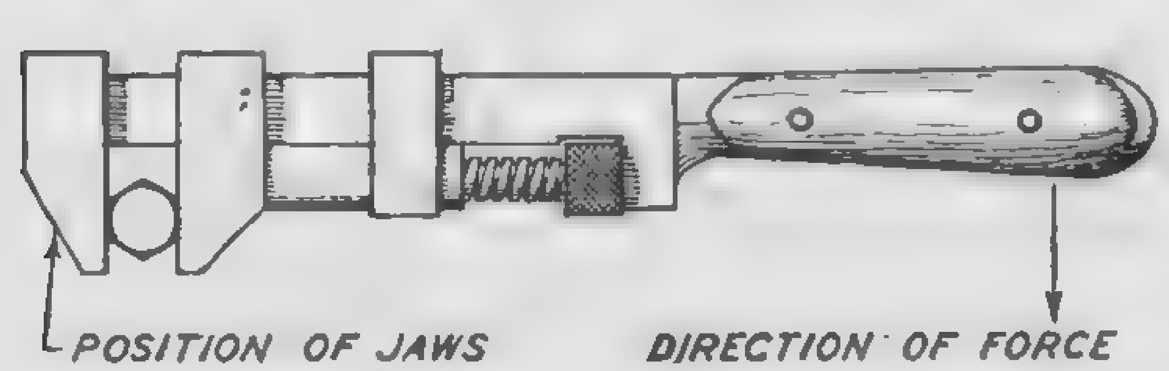



Fig. 12. Monkey Wrench

3. When doing heavy work and you are sure that the bolt and the wrench will stand the strain, you can secure greater leverage by putting a piece of pipe over the wrench handle, as shown in Fig. 11. Good judgment must be used when this is done.





### HOW TO USE ADJUSTABLE WRENCHES

1. Place the wrench on the bolt to be turned. Be sure jaws are pointed in the direction in which the work is to be turned.

2. Adjust the jaws until they fit the part tightly, as shown in Fig. 12.

### QUESTIONS

1. *Is a wrench a lever?*
2. *Why are wrench handles made rather short?*
3. *Why are open-end and closed-end wrenches to be preferred to adjustable wrenches?*
4. *In which direction should force be applied to the monkey wrench?*
5. *Should a large monkey wrench be used to turn small parts? Why?*
6. *Is a push or a blow more effective in loosening a tight nut?*
7. *How can more leverage be secured on a particular wrench?*
8. *Why should a monkey wrench usually not be used around any precision or production machinery?*

## THE BENCH VISE

In order that work may be held rigidly for the performance of hand operations, the machinist uses what is termed a vise. Vises are made in a great variety of forms and sizes, but all consist essentially of a fixed jaw, a movable jaw, a screw, a nut fastened to the fixed jaw, and a handle by which the screw is turned in the nut to bring the movable jaw into position. The sectional view, Fig. 13, shows

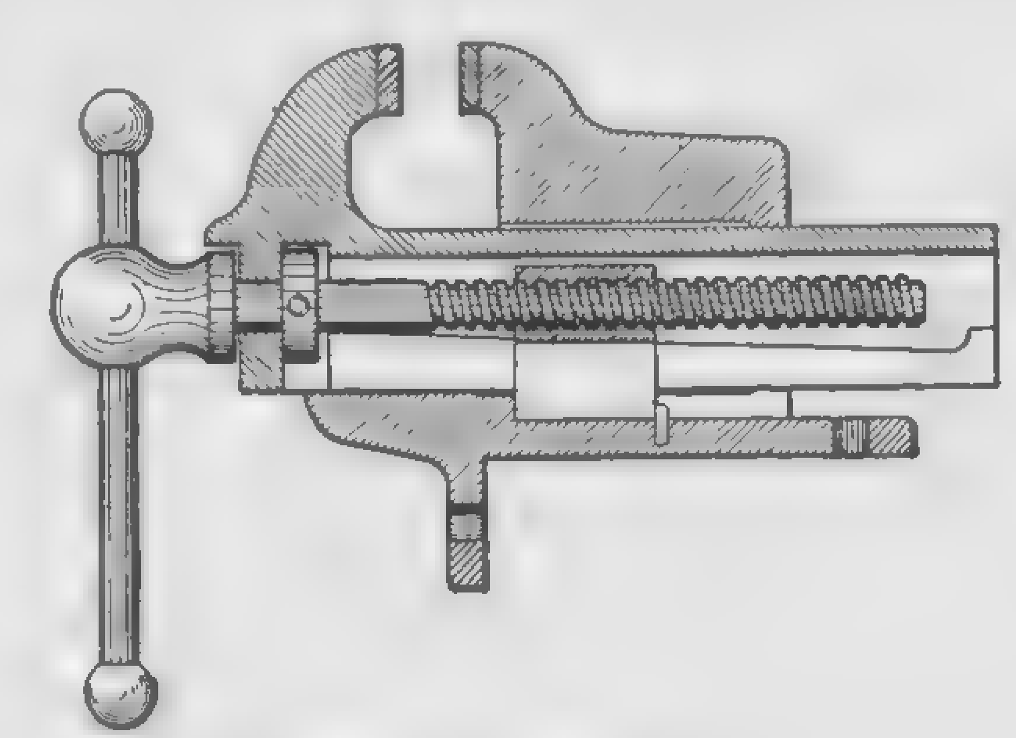


Fig. 13. Bench Vise

these parts clearly and also a device, present in some form in all vises, by which the movable jaw is separated from the fixed jaw when the screw is backed out of the nut.

In the machinist's vise, both jaws are made of cast iron with removable faces of cast steel. These may be checkered to provide a firm grip for heavy work, or may be smooth to avoid marking the

surface of the plate operated upon. When holding soft metal, even the smooth steel jaws would mar the surface; and in such cases it is customary to use false jaws of brass or Babbitt metal, or to fasten leather or paper directly to the steel jaws to protect the work. The screw and handle are made from steel and the nut from malleable iron.

The common method of fastening a vise to the bench is by means of the fixed base, although a swivel base, as shown in Fig. 14,

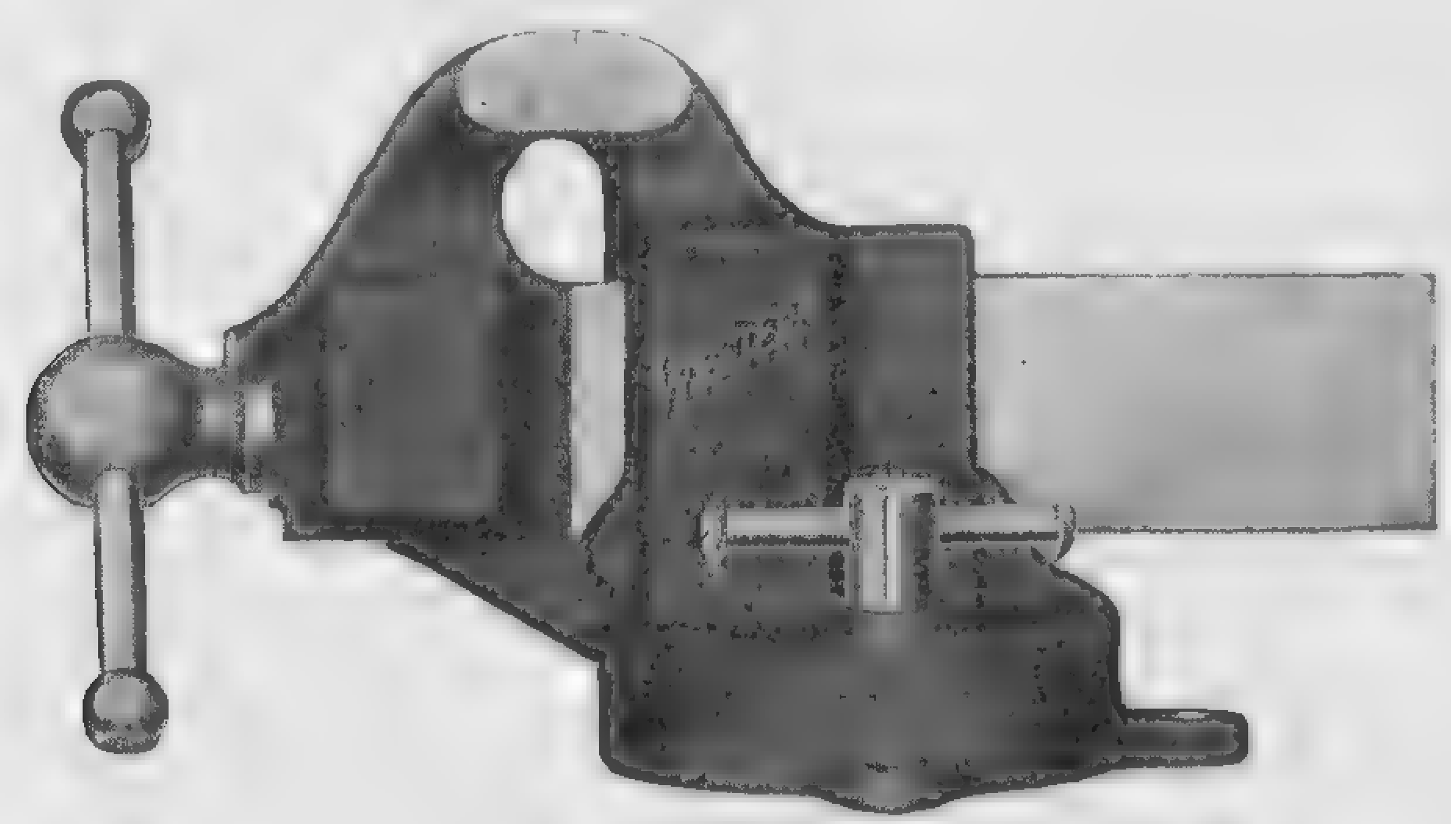


**Fig. 14.** A Machinist's Vise Having Solid Jaws and a Swivel Base
The slide for the movable jaw should never be used as an anvil as that will cause it to spring out of shape and bind in its guide.
*Courtesy of Western Tool & Mfg. Co., Springfield, Ohio*

is preferable. Another type of vise in common use has a swivel jaw, which enables it to hold tapered work firmly. This swivel jaw is provided with a locking-pin, which fixes the jaws in a parallel position. The height of the vise from the floor depends somewhat on the class of work to be performed, but a general rule is to have the top of the jaws about 1½ inches below the point of the elbow when standing erect beside the vise. The vise is indispensable to the toolmaker when filing or when laying out work.

### HOW TO USE THE BENCH VISE

1. Clean the vise daily and keep the clamp screw oiled.
2. When clamping finished work on soft metals, always place a pair of soft jaws over the regular jaws. The false jaws may be made from copper, brass, lead, or leather.
3. Place a block below the work, as shown in Fig. 15, to keep it from slipping down between the jaws.





4. Use judgment in tightening the vise. Be careful not to press cylindrical pieces out of round or to crack light pieces and metals.
5. Never strike the vise handle with a hammer or other object to tighten it.
6. Never pound work on the movable jaw.

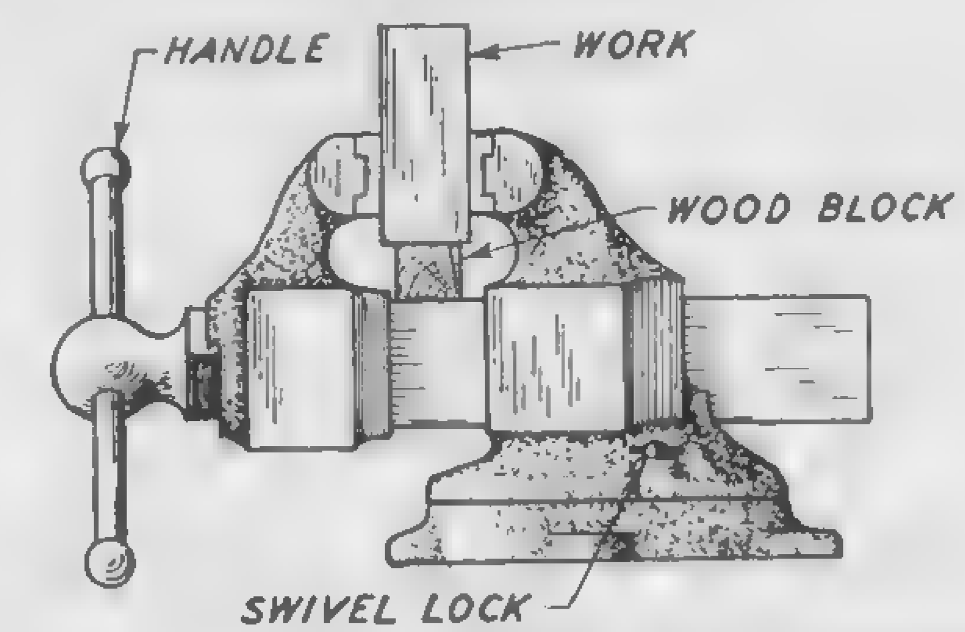



**Fig. 15.** Correct Way to Hold Work in a Bench Vise

### QUESTIONS

1. *How are false jaws held on the regular vise jaws?*
2. *For what are soft, false jaws used?*
3. *From what materials are soft, false jaws made?*
4. *How can you prevent work from slipping down between the jaws?*
5. *Which jaw is movable; which is fixed?*
6. *Why should the front jaw never be used as an anvil for pounding anything?*
7. *Give three important directions for clamping work.*

## THE HACK SAW

**HACK SAW FRAMES.** Hack saw frames are either fixed or adjustable. They are made to take 8-, 10-, or 12-inch blades. Tension

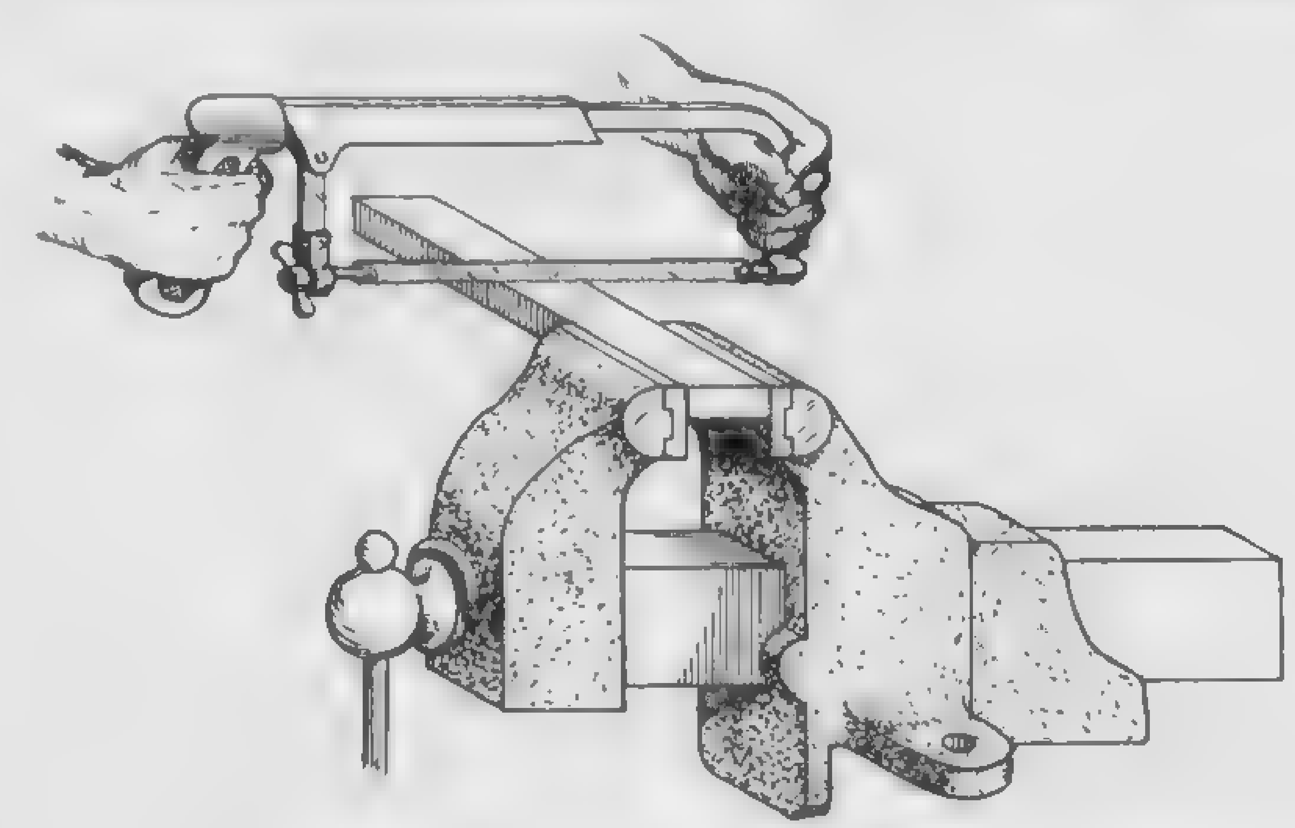


**Fig. 16.** Correct Position of Hands for Sawing with a Hand Hack Saw
Stock may be sawed on either the right or the left side of the vise. Sawing should be done as close to the vise as convenient.

is applied to the blade to make it taut by means of a wing nut on the pistol grip type frame or by turning a threaded handle on the straight handle type. See Fig. 16.

**HACK SAW BLADES.** Hack saw blades are made from high-grade steels, hardened and tempered. Since they are very hard they are also very brittle. Some blades, however, are more flexible because only the teeth are hardened, leaving the blade comparatively flexible.

**PROPER PITCH.** Pitch refers to the number of teeth per inch. Sixteen pitch means 16 teeth to the inch. Pitch is always the most important factor to consider when cutting. When cutting small size stock, be sure to use a pitch which will have at least two teeth always in contact with the sawed surface. See Fig. 17.

The most important consideration in the use of the hacksaw is the selection of the proper blade. One of the chief causes of the breakage of blades is due to teeth or pitch unsuited to the work. Table 1 shows the proper pitch for various types of materials.

### HOW TO USE THE HACK SAW

You will find the following procedures helpful in learning to use properly the hand hack saw.

1. Hold the stock to be cut securely in a vise, so that the saw will cut about ¼ inch from the vise jaws. Cutting close to the vise prevents the stock springing. The cut should be parallel to the side of the vise, as in Fig. 18.

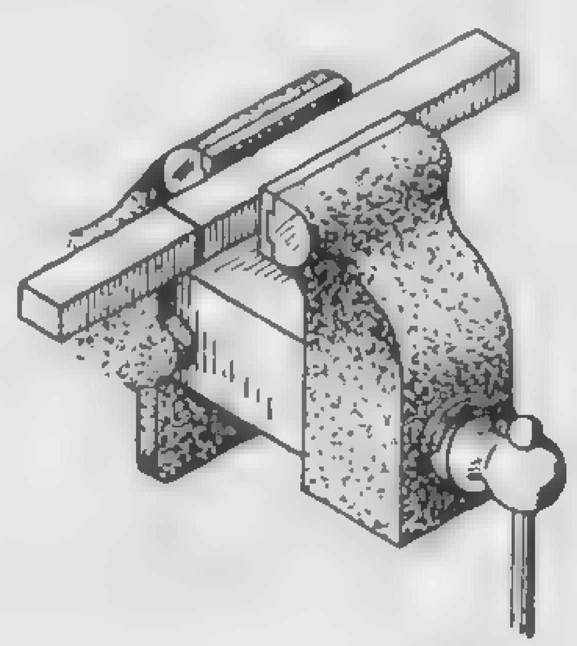


Fig. 18. Cut Parallel to Side of Vise Jaws and Near Vise Jaws

2. To start the saw cut in the right place, make a small nick in the stock with the edge of a file.
3. Hold the frame handle securely in the right hand. Keep the thumb on top of handle. Hold the front end of the frame with the left hand to guide the saw and to give pressure when sawing.
4. Keep the cut straight. If the cut "runs," turn the stock and start a new cut.
5. About sixty strokes per minute is the best cutting speed. Because the teeth point away from the operator, the forward stroke is the cutting stroke. Pressure should not be used on the return stroke.
6. If the blade breaks in a partly finished cut, start the new blade in another





**Table 1—Pitch for Various Materials**

| Pitch of Blade (Teeth per inch) | Stock to be Cut | Explanation | Correct Pitch | Incorrect Pitch |
|---|---|---|---|---|
| 14 | Machine steel<br>Cold rolled steel<br>Structural steel | The coarse pitch makes saw free and fast cutting | Plenty of chip clearance | Fine pitch<br>No chip clearance<br>Teeth clogged |
| 18 | Aluminum<br>Babbitt<br>Tool steel<br>High speed steel<br>Cast iron | Recommended for general use | Two or more teeth on section | Coarse pitch straddles work stripping teeth |
| 24 | Tubing<br>Tin<br>Brass<br>Copper<br>Channel iron<br>Sheet metal (over 18 gage) | Thin stock will tear and strip teeth on a blade of coarser pitch | Plenty of chip clearance | Fine pitch<br>No chip clearance<br>Teeth clogged |
| 32 | Small tubing<br>Conduit<br>Sheet metal (less 18 gage) | | Two or more teeth on section | Coarse pitch straddles work |

Fig. 17. Correct and Incorrect Pitch

place. The new blade is always thicker than a worn blade; hence, the new blade will bind if used to continue an old cut.

7. Do not use oil as a hack saw lubricant in hand sawing.

### HINTS ON USING THE HACK SAW

1. To saw thin stock, clamp the stock between two pieces of wood or soft steel and saw through all three pieces.
2. Four common causes that break saw blades are as follows:
   (a) Using too coarse a blade on thin stock.
   (b) Cutting at an angle, then trying to cut straight.

(c) Exerting too much pressure.
(d) Work insecurely clamped.

3. After replacing a worn blade with a new one, start a new cut because the cut of the old blade will be more narrow than that of the new blade. The new blade will probably break if forced into the old cut.

4. The following suggestions are given for holding the work in the vise properly:

(a) Expose as much of the work as possible so that the maximum number of teeth may be engaged in the cutting.
(b) Be sure the work is held rigidly.
(c) Always start the cut with the least possible angle facing the thrust of the saw teeth.

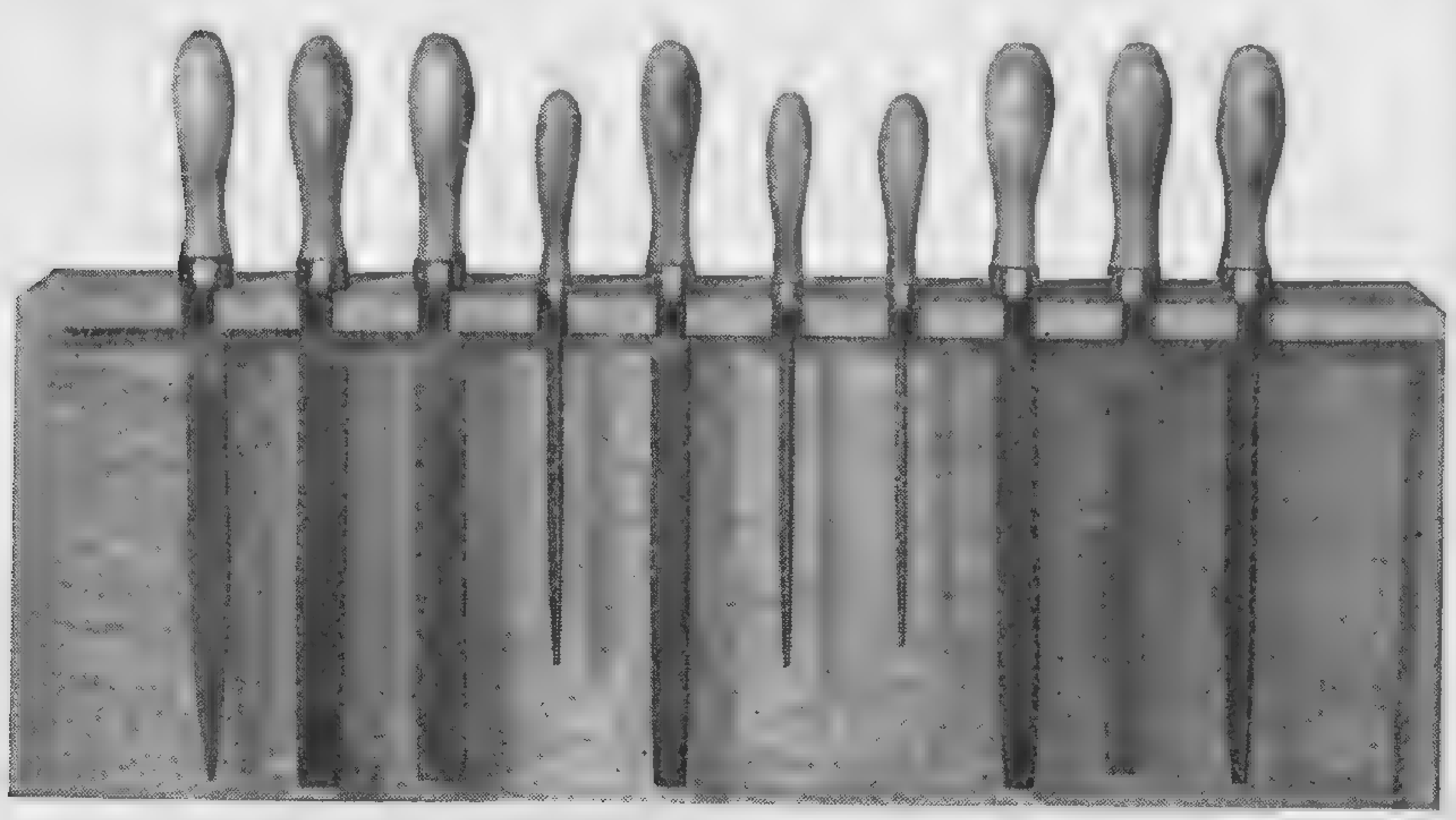
The above points are especially important in cutting such shapes as angle iron or other odd shaped material.

(d) To prevent chattering, saw as close as possible to the vise where work is held.

5. Do not use excessive pressure and saw carefully when the saw is almost through the cut.

### QUESTIONS

*1. Which stroke is the cutting stroke?*
*2. Which way should a saw blade be placed in the frame?*
*3. Does the saw cut on the return stroke?*
*4. What makes the hack saw blade rather brittle?*
*5. In what position should a piece of flat stock about 1/4 inch by 1 inch be placed in the vise for cutting?*
*6. Make a sketch showing the position in which you would hold a piece of angle iron for cutting.*
*7. What is meant by pitch?*
*8. What general rules or principles can you give for selecting blades of proper pitch?*



STANDARD TYPES OF FILES
*Courtesy of The Nicholson File Co., Providence, Rhode Island*



# Chipping, Filing, and Scraping

## CHIPPING

**CHISELS.** The simplest form of metal-cutting tool is the chisel. The several types in common use are shown in Fig. 1.

**Flat Chisel.** The flat chisel is used for snagging castings, for chipping surfaces having less width than the edge of the chisel, and

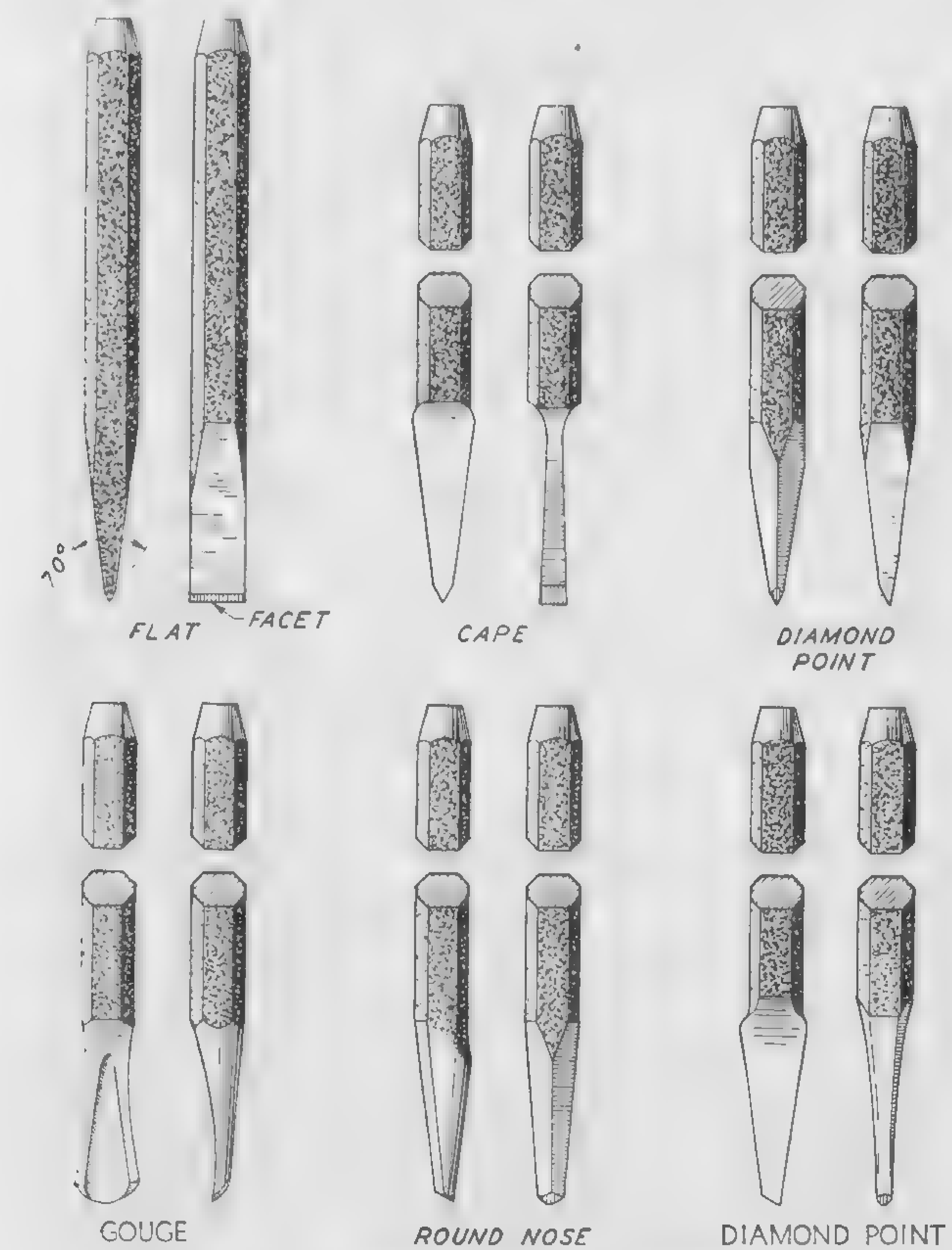



Fig. 1. Types of Chisels in Common Use

for all general chipping operations. It is the form most commonly used, and is often called the cold chisel. Generally, it has a cutting edge about an eighth of an inch wider than the stock from which it is forged.

**Cape Chisel.** The cape chisel is used for cutting keyways, channels, etc., and also for breaking up surfaces too wide to chip with the flat chisel alone. Channels are driven across such a surface, leaving raised portions or *lands* to be removed by the flat chisel. The cutting edge of this chisel is usually an eighth of an inch narrower than the shank, and the part just in the rear of the cutting edge is made thin enough to avoid binding in the slot. As this weakens the chisel, it is made comparatively thick in the plane at right angles to the cutting edge.

**Diamond Point.** The diamond point chisel is made by drawing out the end of the stock to about $\frac{5}{16}$ inch square, and grinding the end at an angle with the axis of the chisel, leaving a diamond-shaped point. It is used for drawing holes, making oil grooves, and cutting holes in flat plates.

**Round Nose.** The small round-nosed chisel is cylindrical in section near the cutting end, the edge being ground at an angle of 60 degrees with the axis of the chisel. When used to *draw* the starting of drilled holes to bring them concentric with the drilling circles, they are called center chisels. The round-nosed chisel is also used for cutting channels, such as oil grooves and similar work. The larger sizes of round-nosed chisels are of the general shape of the cape chisel with one edge rounded, making a convex cutting edge. Large round bottomed channels and all concave surfaces are the proper work of the round-nosed chisel.

All the accompanying forms should be made from a good grade of tool steel, carefully forged, hardened, and tempered to a purple color. The stock generally used is octagonal, and the chisels for heavy work are about 8 inches long and ¾ inch across corners.

**CUTTING EDGE OF CHISEL.** The two bevels forming the cutting edge of a chisel should make with each other as small an angle as is possible without leaving the cutting edge weak. If the angle is too small, the chisel will soon become dull, while if large, more force will be required to drive it. The best angle for cutting cast iron, all things considered, is about 70 degrees, while for wrought iron and





mild steel a slightly smaller angle, say 60 degrees, will be better. When there are two bevels, they should be alike in width and form equal angles with the center line of the chisel. Small round-nosed chisels and some slotting chisels are ground one-sided, that is, with but one bevel, like a wood chisel. The angle between the surfaces which form the cutting edge should be the same, whether these surfaces are both bevels, or one a bevel and the other the straight side of the chisel. In a one-sided chisel, therefore, the angle that the bevel forms with the center line of the chisel should be twice as large as in one having two bevels.

To cut well, chisels must be sharp. Hence, they should be ground at once when they become dull.

### HOW TO GRIND A COLD CHISEL

1. Hold chisel, as shown in Fig. 2, with left hand resting on the tool rest.
2. Do not hold the chisel against the wheel with too much pressure, or temper will be taken out.

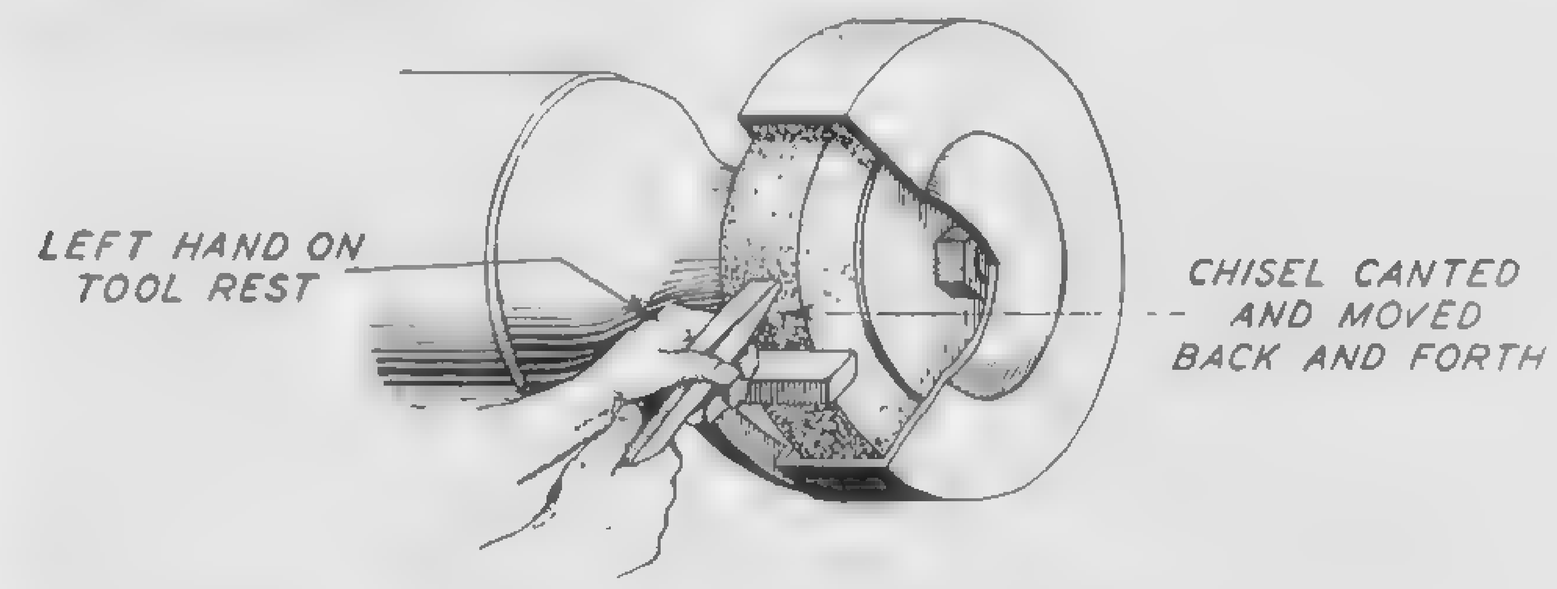



Fig. 2. Correct Way to Hold a Cold Chisel When Grinding

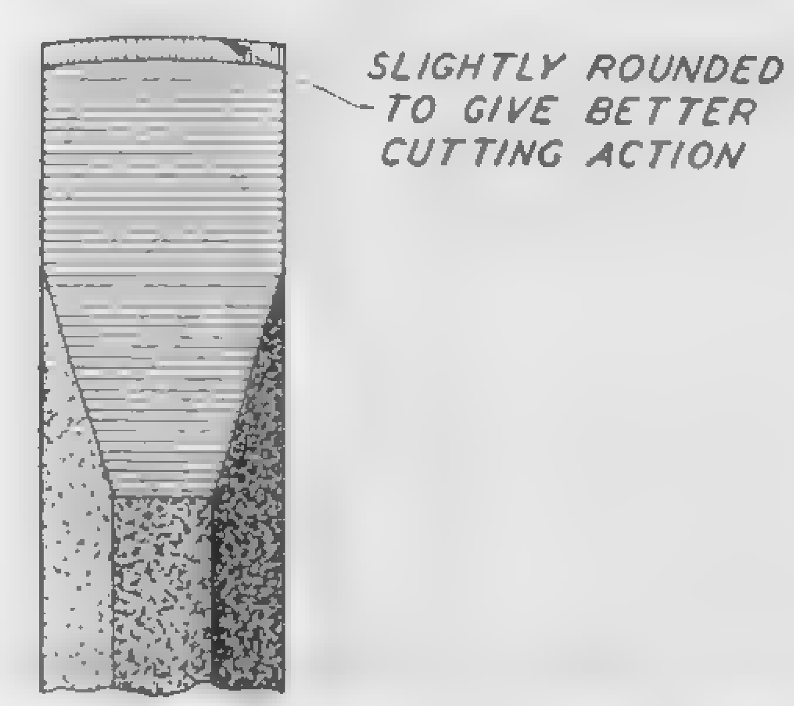



Fig. 3. Cutting Edge Correctly Ground

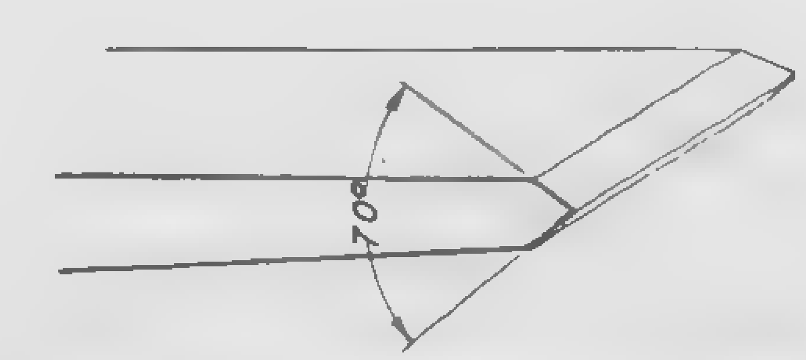



Fig. 4. Correct Angle at Cutting Edge

3. Hold the chisel slightly canted and move slowly back and forth across the face of the grinding wheel. This will give you a flatter and a better facet.
4. Grind the cutting edge slightly convex, see Fig. 3. If this is done, the corners are less likely to dig into the work being chiseled.

5. Do not grind the chisel with too sharp a cutting angle. The best angle is 70 degrees, which is almost a right angle. See Figs. 4 and 5.

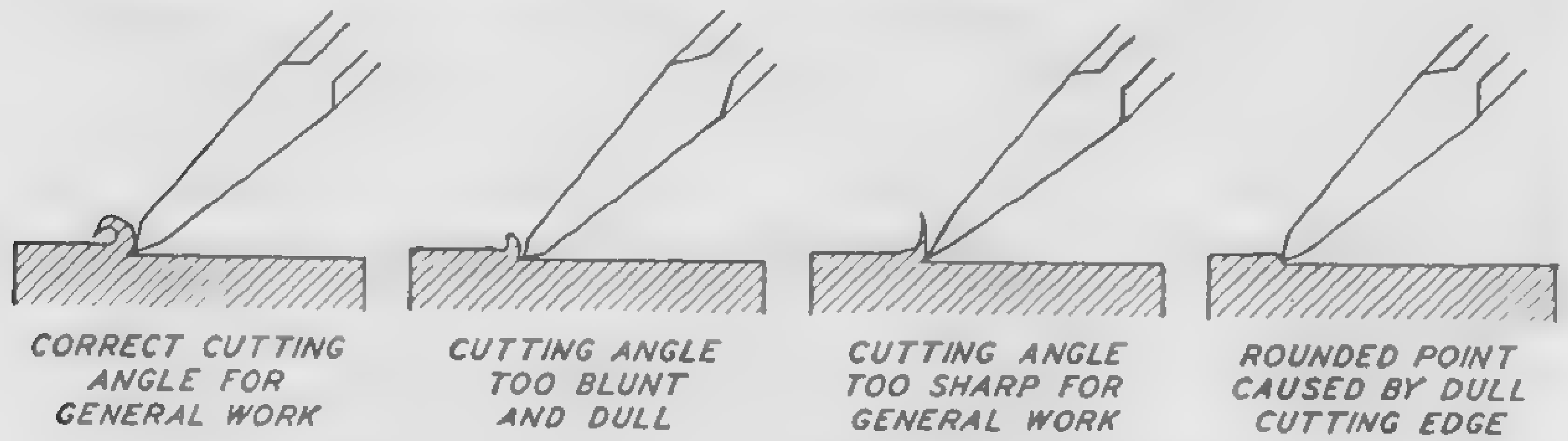



Fig. 5. Good and Poor Cutting Angles on Cold Chisels

**CHIPPING.** Chipping is a term applied to the removal of metal with the cold chisel and hammer. The degree of accuracy required varies. The piece is held in a vise, and the method of working is to grasp the chisel firmly with the left hand, holding the cutting edge to the work and striking the head of the chisel with the hammer, keeping the eyes on the edge of the chisel to watch the progress of the work, Fig. 6. The lower side, or bevel of the chisel, is the guid-

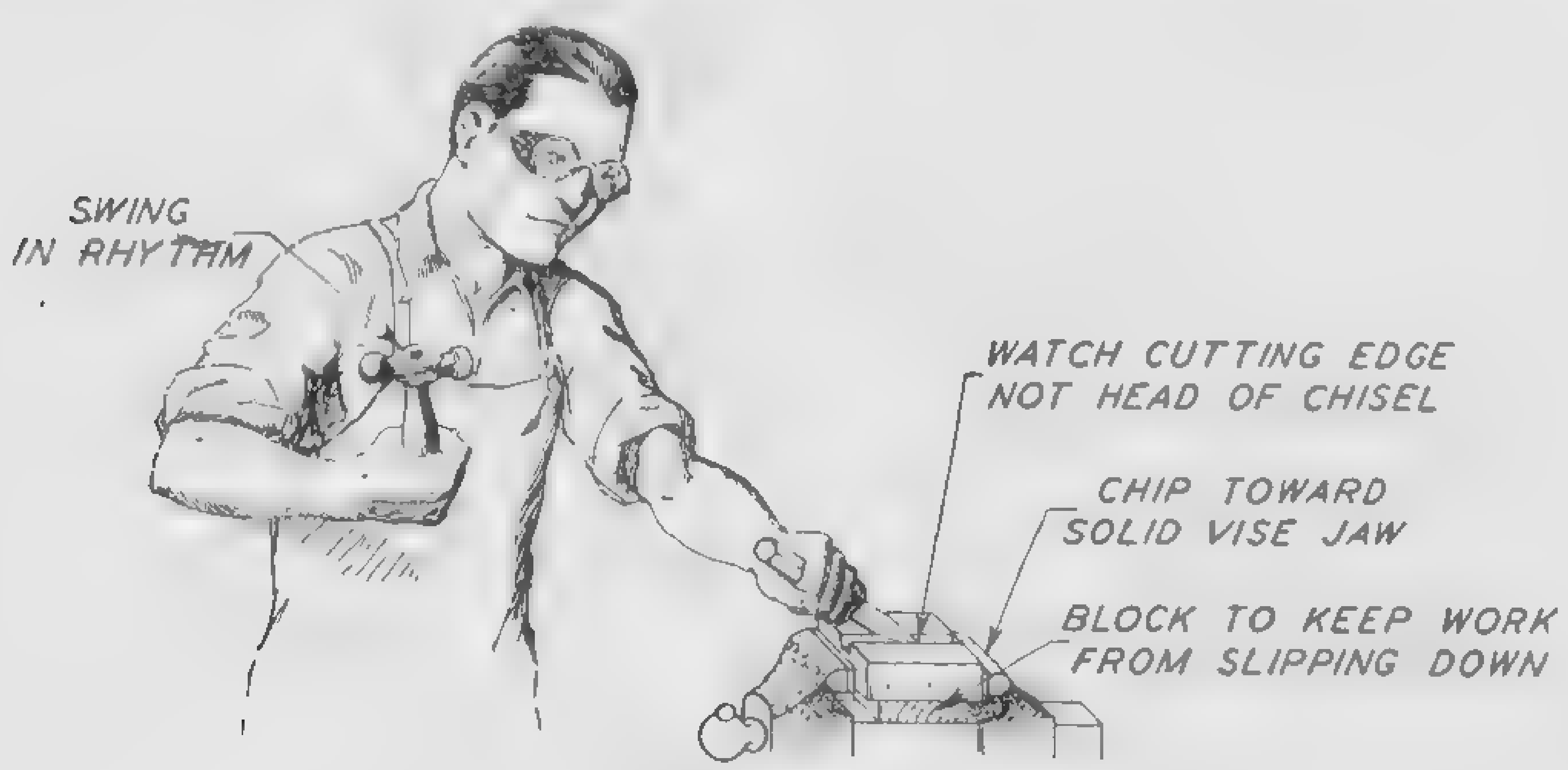



Fig. 6. Correct Technique in Chipping

ing surface and is held at a very slight angle with the finished portion of the work, the cutting edge only touching. Raising or lowering the shank of the chisel increases or decreases the inclination of the guiding bevel and causes the chisel to take a heavier or lighter cut. If the hand is carried too low, the chisel will run out before the end of the cut; while if the hand is raised too high, the progress will be slow, owing to the resistance offered by the metal to separation.

When chipping wrought iron or steel, a piece of waste saturated with oil should be kept on the bench and the edge of the chisel fre-





quently thrust into it. This lubricates the surfaces in contact and preserves the cutting edge of the chisel. While lines are used as guides in chipping operations, it is never advisable to bring the surfaces too near them with the chisel; sufficient stock must be left so that the surfaces may be finished with a file. This is to be observed especially in chipping keyways with a cape chisel; an ample margin for filing should be left both on the sides and on the bottom.

### HOW TO CHIP

1. Wear goggles. Always place a canvas chipping guard in front of the work. This keeps flying chips from hitting men working in front of you.
2. Always use a well-sharpened chisel. Sharpen when necessary, grinding a small amount at a time.
3. When work is secured in a vise, place block under work to prevent it from slipping down.
4. For most ordinary chipping with a $\frac{3}{4}$-inch chisel, use about a 1 pound hammer. Use a light hammer for a small chisel.
5. Begin at the ends and chip toward the middle of the work when chipping cast metal to keep from breaking corners and edges.
6. With every two or three blows, draw the chisel back slightly from the chip. This gives you better control over the job and tends to ease your muscles.
7. $\frac{1}{16}''$ to $\frac{3}{32}''$ is a deep enough cut.
8. Leave $\frac{1}{32}''$ for the finishing cut.
9. Be sure the chisel is sharp when making the finishing cut.
10. Sometimes a rather wide surface needs to be chipped. In this case, first use a cape chisel to cut grooves; second, use the flat chisel to chip the stock between the grooves.

### QUESTIONS

1. *Why should the surface of a casting be chipped before it is filed?*
2. *What kind of chisel should be used on a broad surface?*
3. *What precaution should be taken when you are chipping to the edge of a cast-iron plate?*
4. *Describe how to hold the hammer and chisel.*
5. *How should the work be supported to keep it from slipping down between the vise jaws?*
6. *Examine a properly ground chisel. Is the cutting edge straight or slightly convex? Are the facets flat?*
7. *Use a file to test the hardness of a chisel near the cutting edge. Test it about an inch back from the cutting edge. Which part is the harder? Is it harder or softer than the file?*
8. *A wet grinder is usually preferred to a dry grinder for grinding tools. Why?*
9. *Make a sketch, showing the correct cutting angle for a chisel. Make a second sketch showing cutting angle of 50° and 90°. Why are these angles not good?*
10. *If possible, it is advisable to drill a hole at the end of a keyway which is to be chipped. Why?*

*11. Should you look at the head or at the cutting edge of the chisel when chipping?*

*12. At about what angle should the chisel be held in relation to the work being chipped? Why?*

*13. List several safety precautions to be taken when chipping.*

## FILING

**CHARACTERISTICS OF FILES.** The file differs from the chisel in having a large number of cutting points instead of one cutting edge and in being driven directly by the hand instead of by the

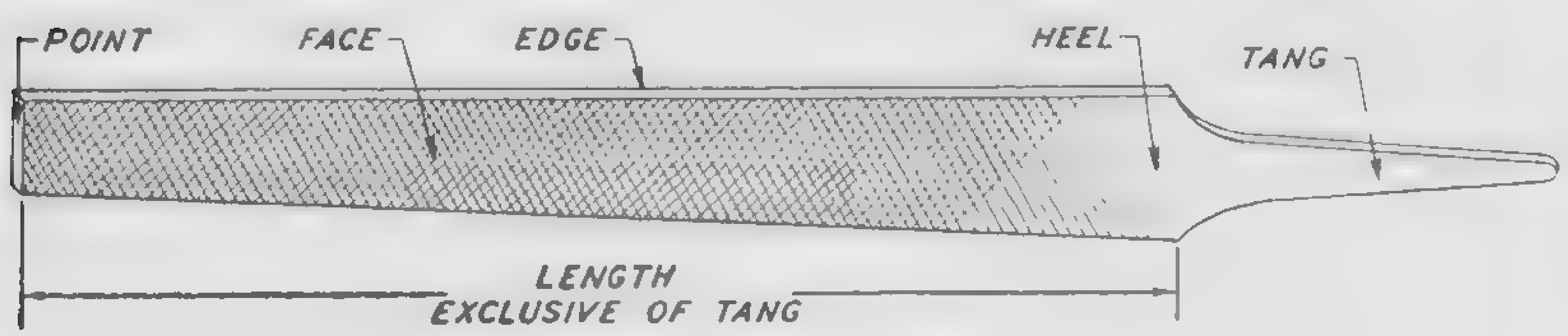



Fig. 7. Flat Hand File

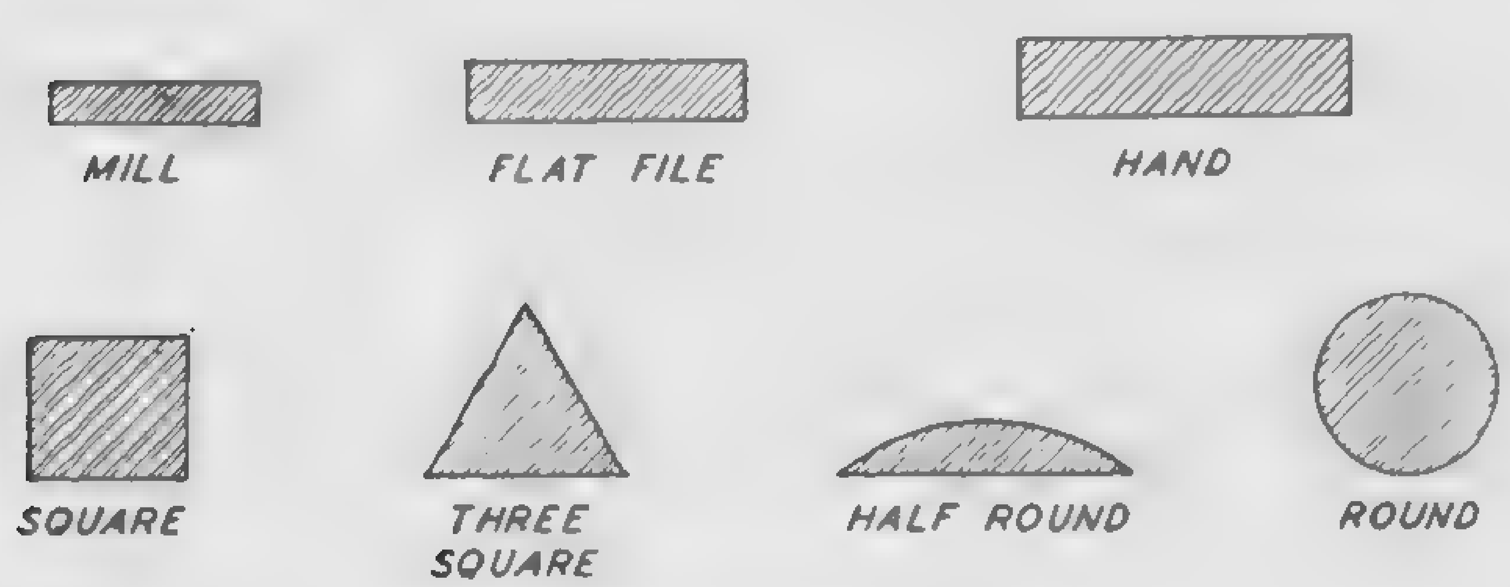



Fig. 8. Cross Section of Files

hammer. As hand power only is used, it is evident that only a small amount of metal will be removed at each stroke.

Files are made from cast or crucible steel and in manufacture pass through the successive processes of forging, annealing, grinding, cutting, hardening, and tempering. They have three distinguishing features—length, kind or name, and cut or coarseness of teeth as shown in Fig. 7. Length is measured from the heel to the point, the tang, which is inserted in a handle, not being included. These lengths vary from 3 inches to 20 inches.

**CLASSIFICATION OF STYLE AND CUTS.** Many kinds of files are manufactured. Those in common use are shown in cross section in Fig. 8.





**Single Cut or Double Cut.** Single-cut files have a single set of teeth cut at an angle of 65° to 85°. Double-cut files have two sets of teeth that cross each other as shown in Fig. 9. One set is usually cut at approximately 45°; the other set is cut at 70° to 80°.

The teeth on a file are cut parallel to each other. They are shaped to make a cutting edge like that of a tool bit, and they have rake and a clearance angle.

**Coarseness.** The coarseness (cut) of smaller files is usually designated by numbers as follows: 00, 0, 1, 2, 3, 4, 5, 6, 7, 8. 00 designates the finest cut and 8 the coarsest cut.

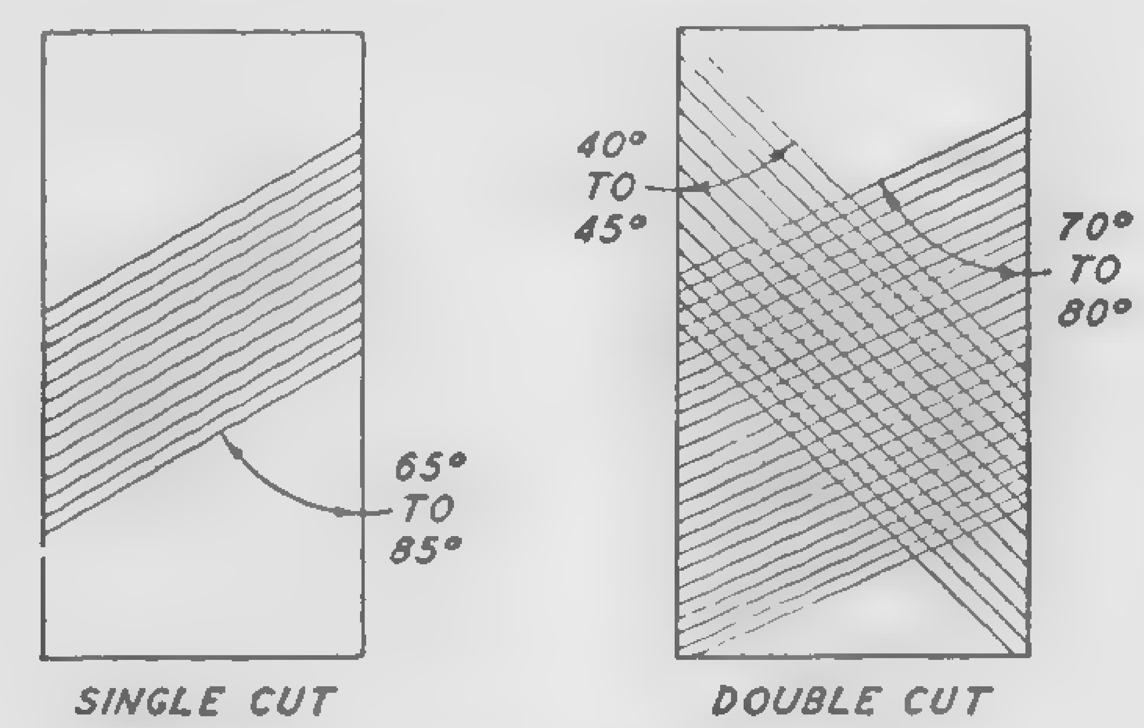



Fig. 9. Single and Double Cut Files

In the larger files the coarseness or cut, Fig. 10, is often designated by the terms: rough, coarse, bastard, second-cut, smooth, and dead smooth.

Although the same series of numbers and terms applies to all files, these designations are relative and depend upon the length of the file; for example, a 16-inch, second-cut file is much coarser than a 10-inch second-cut file.

**FILE HANDLES.** The handles commonly attached to files are of wood and they are made to fit the hollow of the hand. The handle is driven onto the tang of the file, a ferrule on the handle preventing it from splitting. Care should be taken to have the axis of the handle parallel with the file. A good way to prepare the handle for the tang is to heat the tang to a dull red, the file proper being kept cool by a piece of wet cotton waste, and the hole in the handle burned out until the tang is almost in the position it is designed finally to occupy. After cooling the tang, very little driving will be required to fasten the handle to the file securely.

**CONVEXITY OF FILES.** If the cutting surface of a file were perfectly flat, the number of teeth or cutting points engaged with the work would depend on both the width of the file and the width of the piece being filed. To force as many cutting points as would be

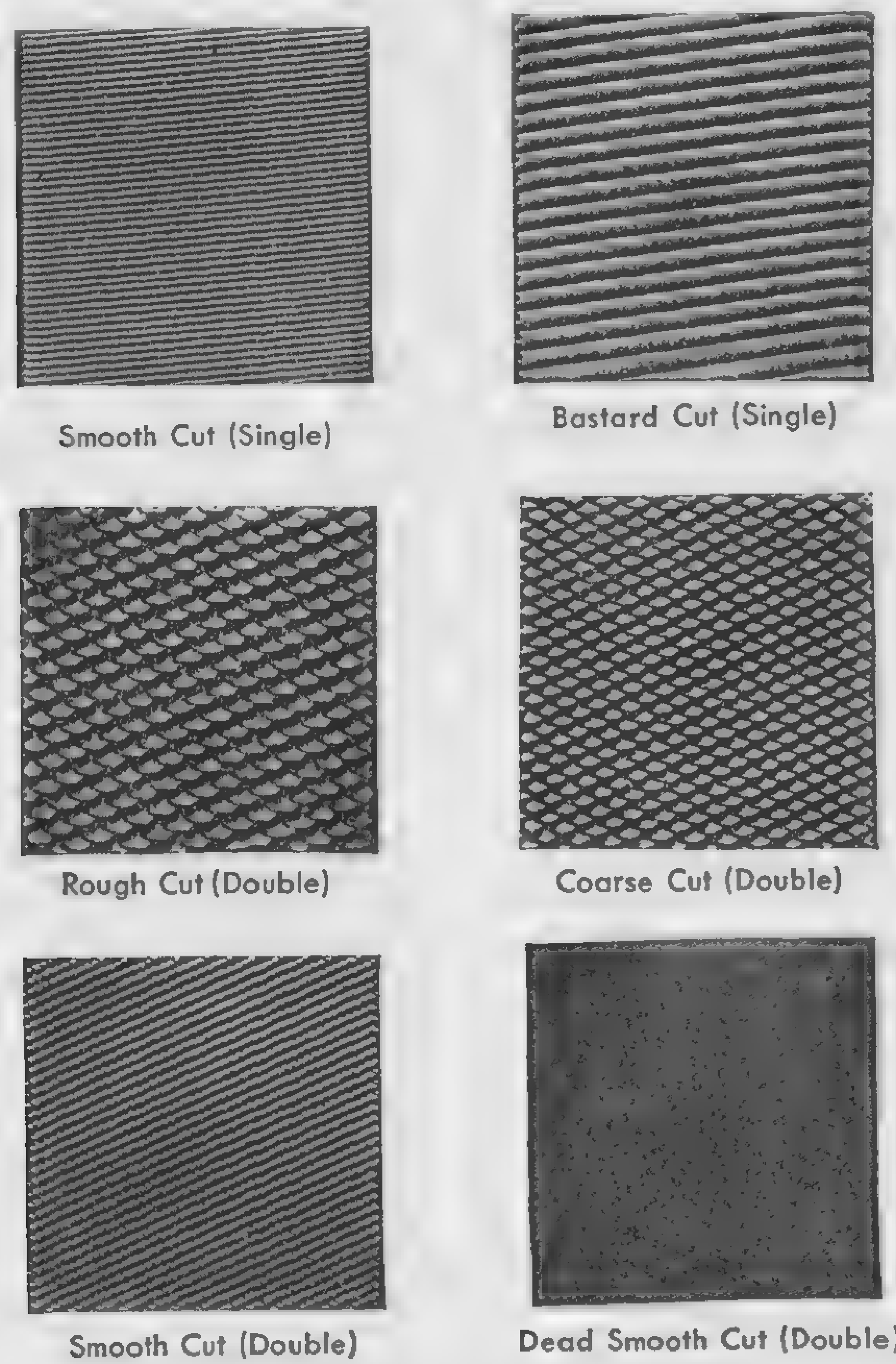



Fig. 10. Coarseness or Cut of Larger Files
There is no established rule fixing any certain number of teeth to the inch for any particular cut. The spacing varies with the length of the file. The longer the file the wider the spacing between cuts.
*Courtesy of Henry Disston & Sons, Inc.*

contained in such a large area deeply enough into the metal to enable each to remove its share of the stock would be beyond the power of the man pushing the file. To avoid this necessity for great pressure, files are usually *bellied* or made slightly convex in the direction of their length, so that, theoretically, the file and the work are in contact only on a line as long as the width of the file. This enables the





file to be forced into the metal sufficiently for the teeth to bite, and thus avoids dulling the teeth, which always occurs when the file is allowed to glide over the work without sufficient cutting.

This convexity of files also serves another purpose. The pressure applied to the file to make it bite bends the file more or less, Fig. 11, and if the file in its natural state were perfectly flat, when cutting it would be concave; and this would prevent the production of a flat surface as it would cut away at the edges of the work, leaving a convex surface. Such files might, however, be used on convex surfaces.

**HEIGHT OF WORK FOR DIFFERENT CLASSES OF FILES.** Work for filing is usually held in a vise, and, under ordinary circumstances, the surface of the work should be about the height of the elbow.

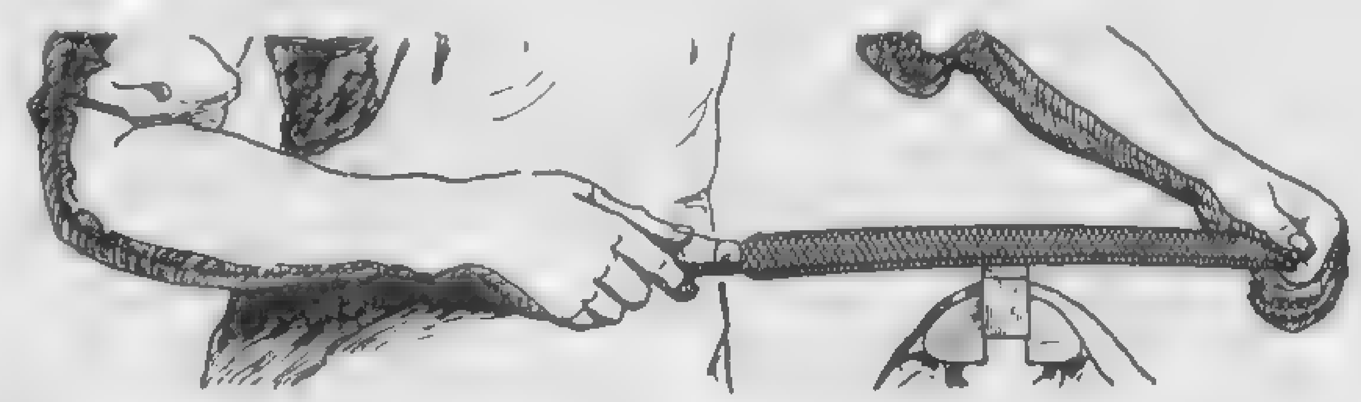


Fig. 11. Showing Slight Curvature of File as a Result of Pressure on Both Ends

For fine work with small files, where close observation is of more importance than pressure on the file, the work should be higher than this, the height increasing with the refinement of the work. On the other hand, for very heavy filing, where great pressure is absolutely necessary, the work should be several inches below the point of the elbow, so that the weight of the body may be used to good advantage, and also because the workman naturally stoops a little when exerting great pressure on the file.

**CHOICE OF FILES DEPENDS ON WORK.** The kind of metal being worked determines in a great measure the character of the file to be used. Cast iron, especially if the scale has not been previously removed, is particularly hard on a new file, as the glassy character of the scale tends to dull the cutting edges. New files should never be used on such a surface.

On tool steel and on hard materials generally, a second-cut file is better than the bastard. This is because if pressure enough is exerted to cause the coarse teeth of the bastard to bite into the work, the teeth, being comparatively long, are very likely to be broken

off. In the second-cut file, the teeth are shorter and present more cutting points in a given area, thus preventing excessive duty being imposed on a few teeth.

Softer metals, such as brass and bronze, allow the use of the coarser grades.

Nearly all files used in the machine shop are double cut. The 10- or 12-inch bastard file is generally used for rough filing bench work, the second-cut file for securing a fairly smooth finish, and as fine a file as necessary for obtaining the desired finish.

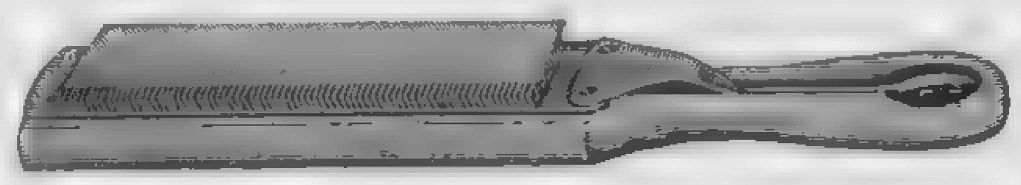


Fig. 12. File Brush

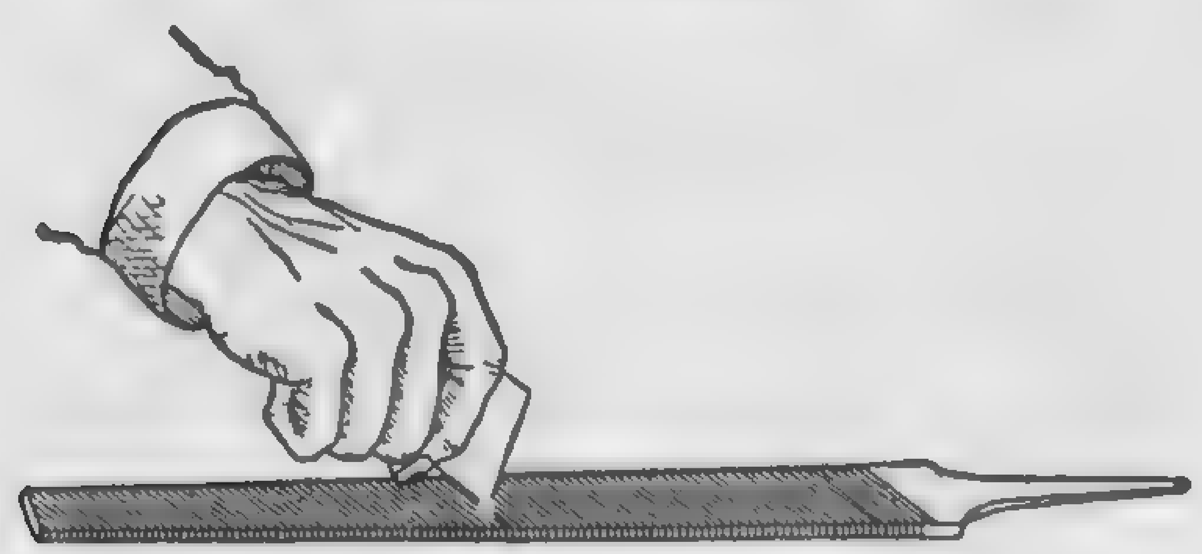


Fig. 13. Removing Pins from a File

The rough, coarse, and dead smooth files are used only infrequently in machine shop work. Among the smaller files, Nos. 00 to 2 are used more than the rest.

**CLEANING FILE.** The particles of metal removed by a file frequently remain in the teeth and diminish their cutting qualities. In the case of hard metals, these particles, or *pins*, often scratch the work. It is necessary, therefore, that files be cleaned frequently. This is best performed by using a stiff brush as shown in Fig. 12. In the finest grades of files, a thin piece of wood or sheet brass may be drawn across the surface of the file as shown in Fig. 13, and the filings are removed by the points extending into the file teeth.

When filing cast iron, neither the file nor the work should be allowed to become greasy, as this tends to make the file slide without cutting. In filing steel, however, if the file be oiled or filled with chalk, the pinning of the file is prevented in a large degree, and frequent use of the card or brush is not necessary.





## HOW TO FILE

**CORRECT FILING POSITION AND TECHNIQUE.** The correct position for filing is about as follows: feet about 8 inches apart and at right angles, the left foot being in line with the file; stand back from the vise so that the body may follow the file slightly; grasp the file handle with the right hand, fingers below, thumb on top of, the handle. For coarse filing, place the ball of the thumb of the left hand on the point of the file, and for fine filing grasp the point of the file with the thumb and forefinger of the left hand. When holding the file in one hand, as is often done in light work, the forefinger should be on top of the file, pointing in the direction of its length. This allows free movement of the hand and wrist, pressure being applied principally by the forefinger.

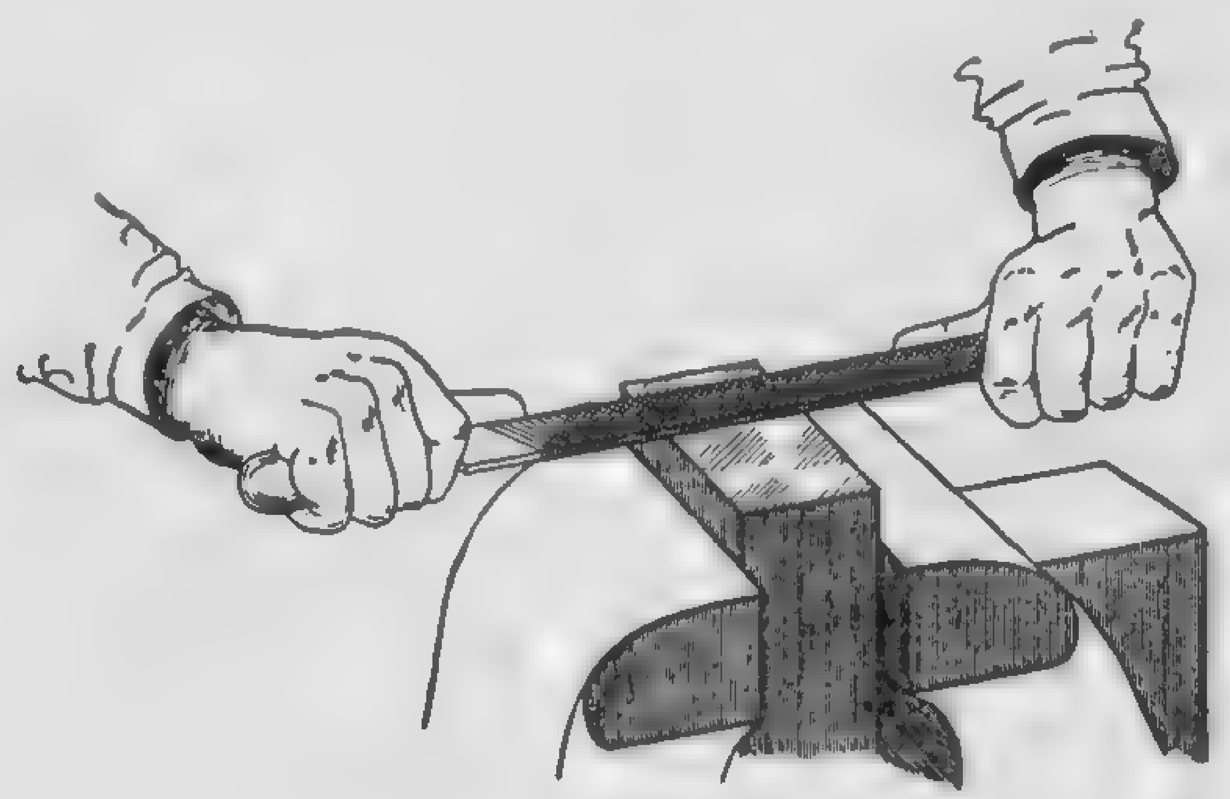


Fig. 14. Draw Filing

As file teeth or cutting edges point toward the end of the file, it is evident that the file can cut only when moving in a forward direction. On the return stroke, the pressure should be relieved; otherwise the teeth will be dulled when drawn back over the surface.

**DRAW FILING.** What is known as draw filing is done by grasping the file toward each end and then pulling and pushing the file along the entire length of the job, Fig. 14. Very little stock is removed by this method, but the object is to lay the file marks parallel to the length of the work. This is done to produce a smooth finish on edges and narrow surfaces. In most cases, draw filing is not considered good practice.

For draw filing, single-cut files are better than double-cut files as they are less likely to scratch the work.

**ROUGH FILING.** When rough filing, cross the stroke at short intervals, Fig. 15. This will help you to keep the surface flat and straight while you are learning to file. Bear down only on the forward stroke.

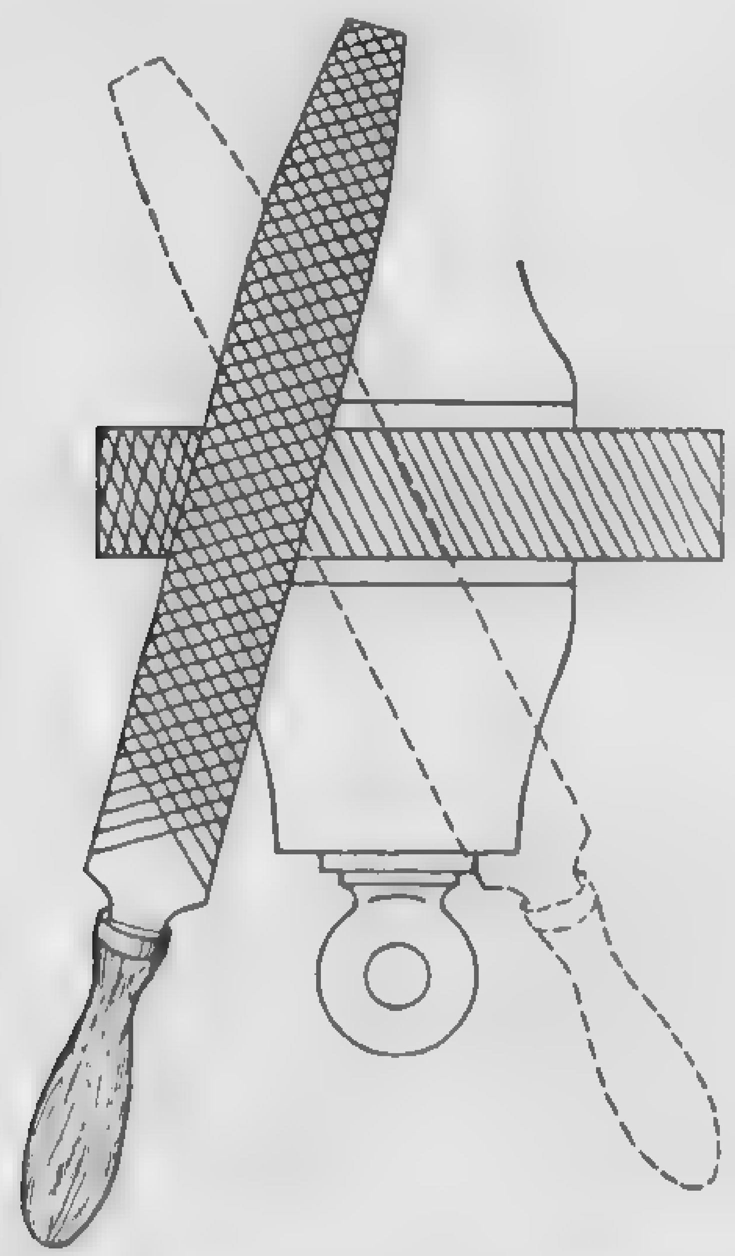


Fig. 15. Crossing Stroke for Rough Filing

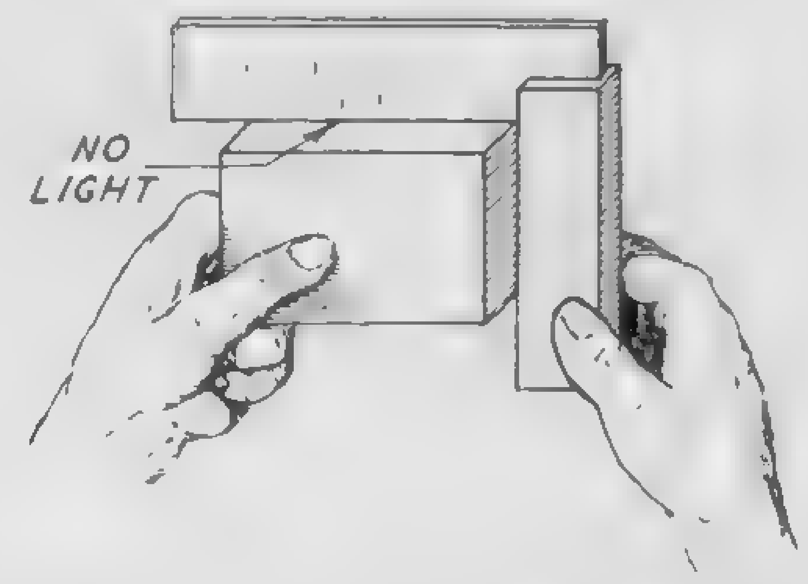



Fig. 16. Test for Squareness

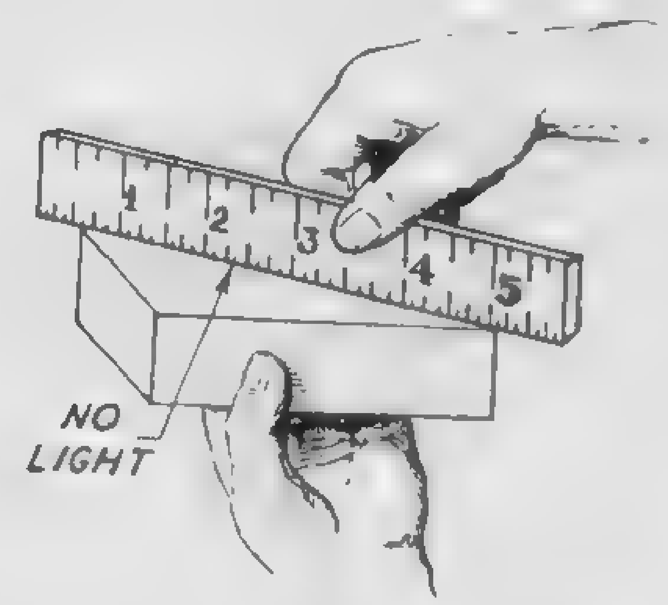



Fig. 17. Test for Flatness Across Corners


Fig. 18. Rounding a Corner

**TESTING THE WORK.** Test the work occasionally with a scale to determine whether the filed surface is flat and straight and with a steel square to determine whether the work is square. See Figs. 16 and 17.

**ROUNDING A CORNER.** To round a corner, Fig. 18, rough file across the piece and reduce the corner by filing a series of angles until the proper radius is secured. Then finish the corner by following along the rounded corner with a fine cut file.





**POLISHING.** No matter how carefully filing is done, it does not leave a surface that is pleasing to the eye; the file marks are more or less irregular and the whole surface is dull. Exposed parts of machines which are not painted are usually polished. Polishing does not necessarily improve the surface, but simply brightens it and renders it more attractive. As a rule, a polished surface is not a true surface, no care being taken to maintain its trueness. In ordinary machine work, polishing is usually done by abrasives, such as emery, corundum, and carborundum; while rouge, crocus, rottenstone, and tripoli are used on fine work, especially on brass and

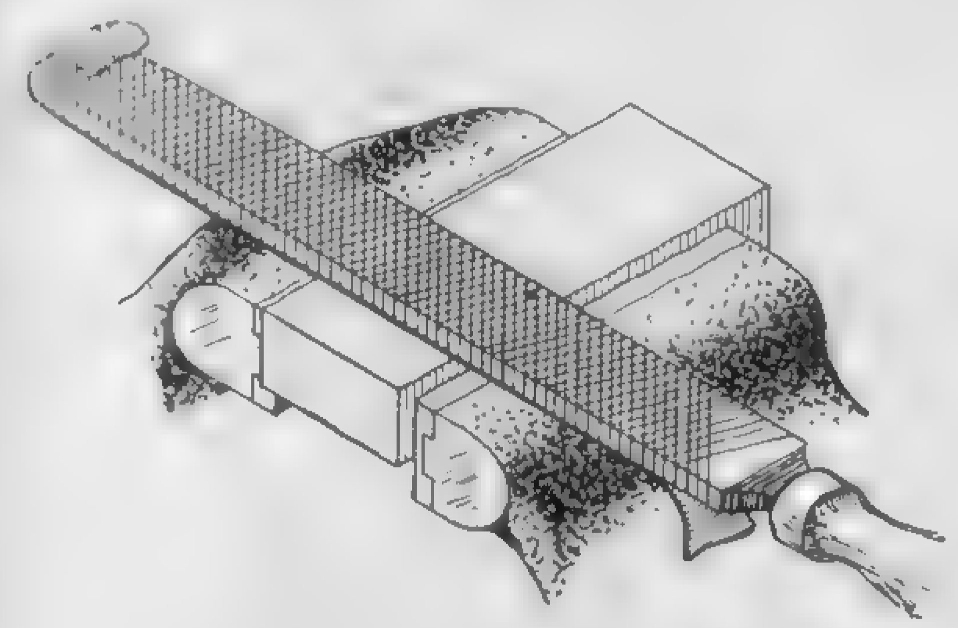


Fig. 19. Polishing with Emery Cloth Held Against Bottom of File

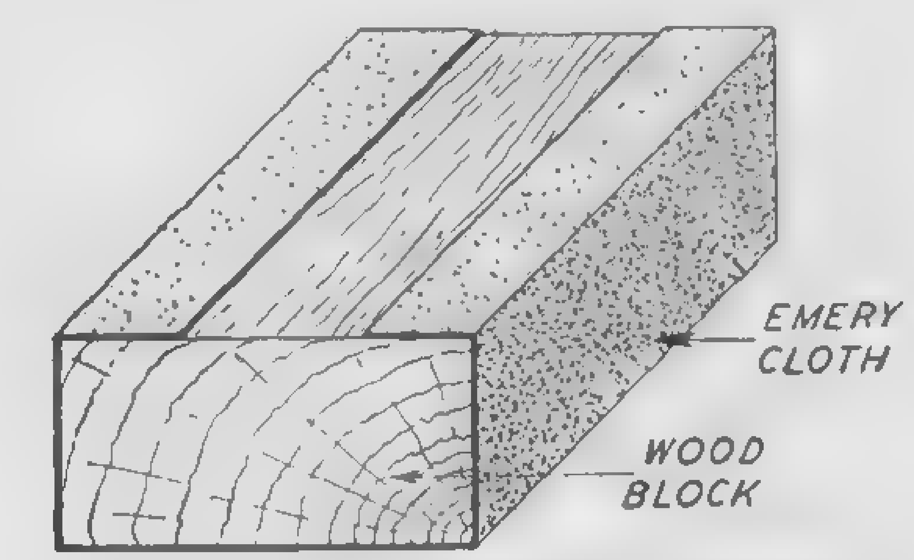



Fig. 20. Emery Cloth Folded Over Block for Polishing

composition. Emery, for example, is crushed and sorted into grades varying from No. 8 to flour, the number of the grade indicating the number of meshes per linear inch in the sieve used in sorting. These grades sometimes bear arbitrary designations, No. 1 indicating a coarse grade and Nos. 0, 00, 000, 0000 showing the finer grades.

**Methods of Using Powders and Cloths.** Emery powders are sometimes mixed with oil and applied directly to the work by wooden blocks or clamps; but the more common method is to use what is known as emery cloth, the grains being glued to a strong cloth backing.

Emery cloth is used in many ways, Figs. 19 and 20. It may be wrapped around a file; folded or tacked to a block of wood; glued to wooden sticks about 15 inches × 1½ inches × ½ inch, fastened around rollers for internal curves, or glued to wooden or steel discs and rotated in a lathe or special machine. In all cases the object is to grind down the surface, using a sufficient number of grades of cloth to produce the degree of polish desired. The marks are laid parallel to each other, making what is known as a *grain*. When the

process is to be carried to such an extent that no grain is to be visible, the finer polishing agents are used, usually applied with a cloth wheel or *lap*. Old cloth does finer work than new, and oil on the cloth will make a finer cut.

### SUGGESTIONS ON FILES AND FILING

1. Filing cast iron. Remove the scale from the surface before filing a cast iron casting.

2. Filing on the lathe. For rough filing the double-cut flat file; for finish filing, the single-cut mill file.

   (a) Method. Use long, slow cuts. Short, quick strokes will make a series of small flats or will get the work out of round.

   Too much filing on the lathe will tend to get the work out of round.

3. Use the correct file for the job. For filing soft metals, as brass and copper, use a brass file with specially designed double-cut teeth. For rapid filing of aluminum, use a file designed for this purpose—a file with a coarse, deep upcut and a fine light overcut which removes metal rapidly but does not clog readily.

4. Keep the file cutting. One of the easiest ways to ruin a file is to use too much or too little pressure. Just enough pressure should be applied to keep the file cutting at all times.

5. Take care of files. Never throw files into a drawer or lay on top of other files. Keep them in a rack and in a dry place.

6. Safety. Never use a file without a handle.

7. Precautions.

   (a) Never rub your hand over the work you are filing.

   (b) Always protect filed surfaces by placing soft material between them and the hard jaws of a vise.

### QUESTIONS

1. *How is a file designated?*
2. *Why are files slightly convex?*
3. *What is meant by crossing the cut?*
4. *Which stroke is the cutting stroke?*
5. *Should the file be lifted from the work on the return stroke? Why?*
6. *What is the difference between a double-cut file and a single-cut file?*
7. *What is the difference between a double-cut file and a second-cut file?*
8. *Should the scale on castings be removed before filing? Why?*
9. *When should the coarser files be used?*
10. *When should the finer files be used?*
11. *What is meant by draw-filing?*
12. *What is meant by pinning? How can the pin be removed?*

## SCRAPING

**HAND SCRAPING.** When two flat or curved surfaces are to be worked together, and close contact over the surfaces of both is desired, they are hand scraped. Scraping removes less metal than





filing and also enables the workman to confine the removal to limited areas. The scraper, which should be made from a very good grade of tool steel, is nearly 2 feet long exclusive of the handle. The general shape is shown in the upper view of Fig. 21. The cutting edge is about $\frac{3}{32}$ of an inch thick and $1\frac{1}{2}$ inches wide. It is ground on an emery wheel or grindstone and carefully oilstoned, leaving the cutting edge as straight as possible. Scrapers are sometimes made from old files, the teeth being ground off and the end drawn out wide and thin. Sometimes the end is bent at right angles to the shank, as shown in the lower view of Fig. 21. The cutting done by scrapers should be perfectly smooth and free from scratches.

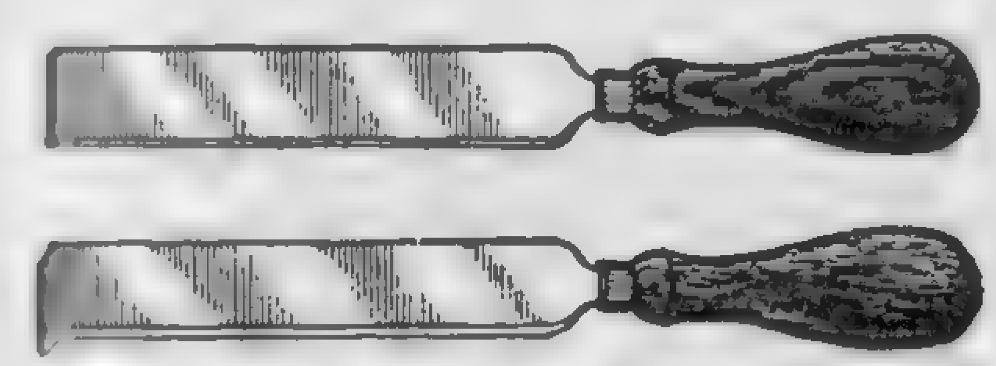


Fig. 21. Straight and Bent Hand Scrapers

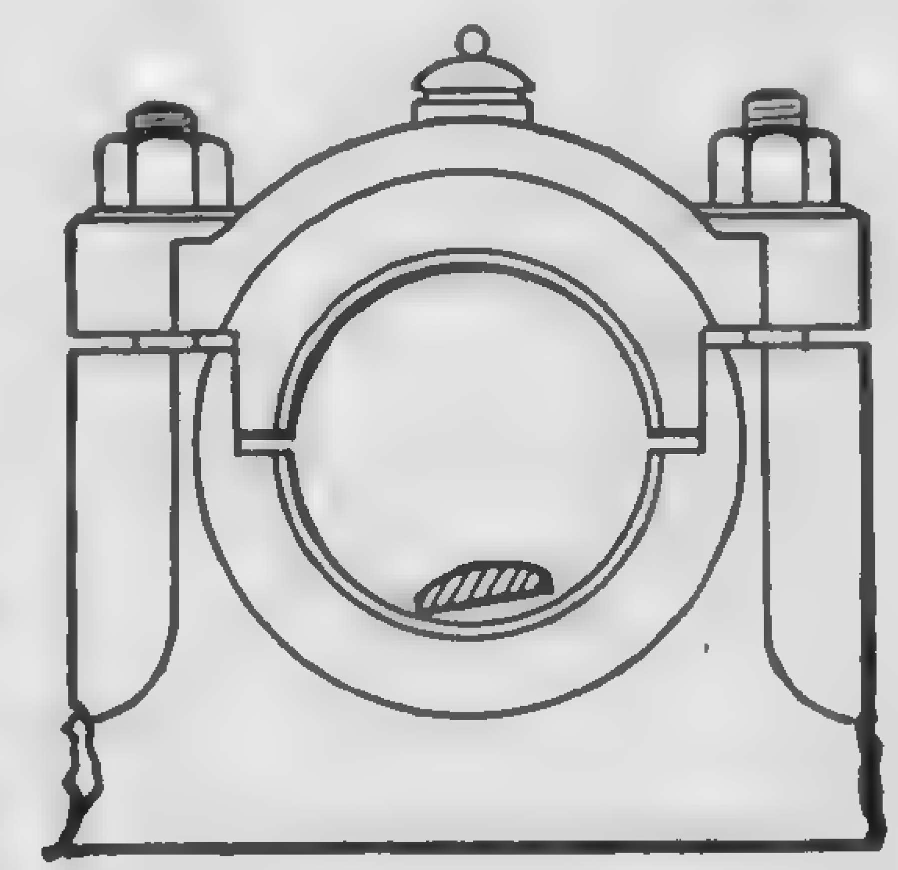


Fig. 22. Scraping Spindle Bearing

**Testing Plane Surfaces.** In using the surface plate as a test for the trueness of a plane, such as a valve or its seat, the plate is covered with a very thin coating of Prussian blue and then rubbed over the valve or seat. The latter should have previously been finished as smoothly as possible. The spots where the blue shows contact are scraped off and the process continued until contact over the entire surface is obtained. During the last part of the operation, alcohol should be used instead of Prussian blue, as it leaves clean bright spots to indicate where the scraper must be applied. The scraper for concave surfaces, such as bearings, is of the general shape of a half-round file without teeth. In such cases, the spindle itself takes the place of a surface plate. The method of holding and using such a scraper is shown in Fig. 22.

**Scraping for Finish Only.** Scraping is sometimes done as a matter of finish, and not for the purpose of getting an accurate surface. It is then termed "spotting." A spotted surface, therefore, does not always indicate accuracy.

### SUGGESTIONS ON SCRAPING

1. The master plate should first be cleaned with gasoline. The Prussian blue may be applied either with the hand or with a rag. Apply generously when rough-

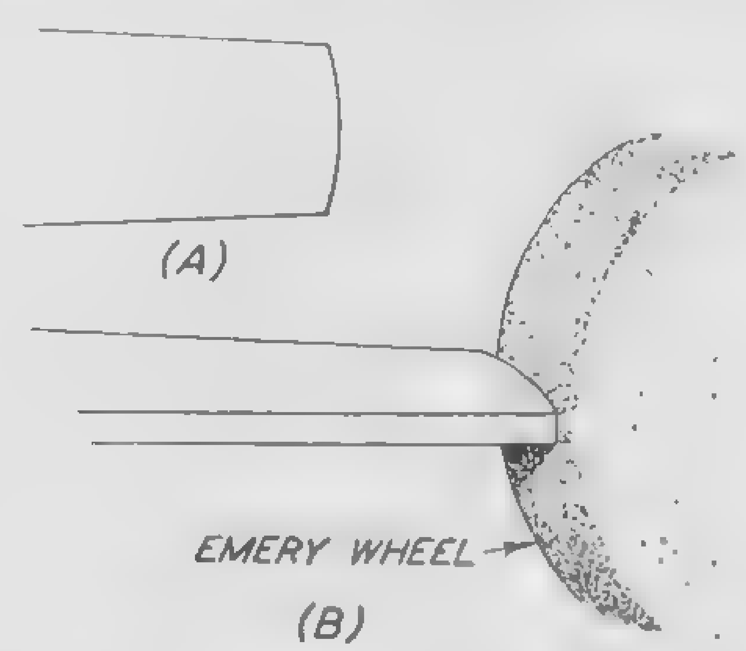



Fig. 23. Grinding a Scraper

ing the work and lightly when finishing. (At the close of the day's work, the master plate must be cleaned free of all Prussian blue and oiled thoroughly to prevent rusting.)

2. Grind the flat side of the scraper to a slight curve as shown in Fig. 23 at (*A*) and the narrow side square as shown in Fig. 23 at (*B*). The scraper should be stoned by pivoting the handle end and swinging the blade end on the oil stone that has previously been soaked with gasoline. To avoid grooving the stone, use the entire surface. The scraper need be ground only after being stoned twenty or thirty times.

3. The scraper must be held at the proper angle to cut freely without gouging. When the scraper is first stoned, it may be held nearly horizontal. As the edge dulls, the scraper should be gradually raised.

4. The scraping should be done in a different direction each time the work is spotted.

5. Be careful to use the entire surface of the master plate so that it will not become excessively worn in any one place. Allow no grit or dirt whatever to remain on the master plate or work when spotting.

6. The work should be machined or filed flat within .002 inch or .003 inch before attempting to scrape.

7. Scrape hard until the surface is covered with closely spaced large spots, then "pick off" only the spots which are blue, and finally only those blue spots with a shiny center.



# Hand Threading

## TAPS AND DIES

**TYPES OF TAPS.** When internal thread cutting is done by hand, the tool used is called a tap. There are many styles of taps, the names in some cases being suggested from the shape, but more often from the use. In most machine shops are found the following forms: hand, machine screw, pipe, pulley, stay-bolt, boiler, and tapper; of these the hand and machine screw are the most common. The object of all is to make helical grooves, called threads, in holes, so that they may receive and hold screws, bolts, studs, etc.

The tap is threaded accurately and fluted. The flutes extend the length of the threaded portion so that a series of cutting edges

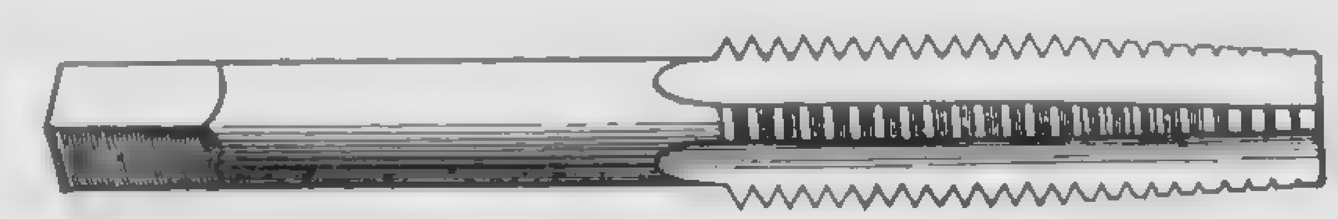


Fig. 1. Taper Tap

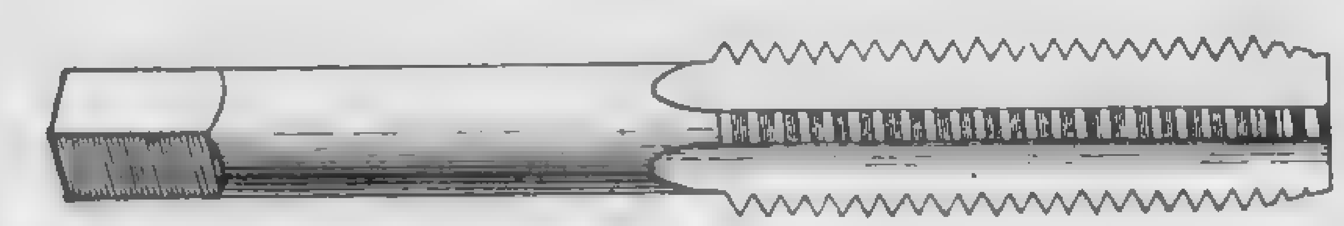


Fig. 2. Plug Tap

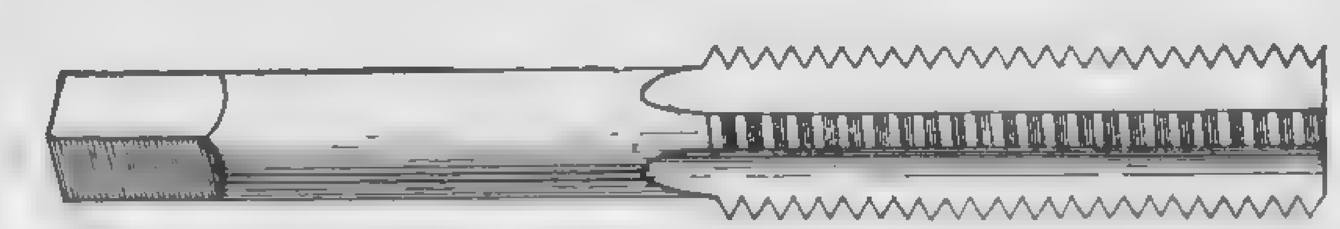


Fig. 3. Bottoming Tap

is formed. Taps are made of tool steel carefully hardened and tempered. The tap is a rather brittle and fragile tool and is easily damaged if not handled carefully.

**TAP SETS.** Standard hand taps over $\frac{1}{4}$ inch in diameter are made in sets of three. These three taps, called (1) taper, (2) plug, and (3) bottoming, are here described and illustrated.

**Taper Tap.** The taper tap, Fig. 1, is used to start the thread. It is tapered or chamfered back from the end at least six threads, before the full diameter of the tap is reached.

**Plug Tap.** The plug tap, Fig. 2, is tapered back from the edge about three or four threads. The plug tap is used after the taper tap has been used to cut the thread as far as possible.

**Bottoming Tap.** The bottoming tap, Fig. 3, is chamfered for about one thread. This tap is used last and is used to drive the thread to the bottom of the hole.

**SIZE OF DRILL FOR TAPPED HOLE.** As the size of a tap is the outside diameter of its threads, it is evident that the hole drilled for tapping must be smaller than the tap by nearly, if not quite, twice the depth of the thread. The shape of the thread partly determines the amount to be subtracted from the tap diameter. There are now recognized as standard, six different threads—National Fine Thread; National Coarse Thread; Whitworth; International or metric; Acme; and the Square. Table 1 shows the diameters of holes that are to be drilled for cutting the various sizes of threads.

**TAP DRILL SIZES.** For commercial purposes tapped threads need not be 100 per cent full thread. The tap drill size is therefore larger than the root diameter of the screw thread. A tap drill that will give approximately a 75 per cent thread is generally used.

FORMULA FOR FINDING APPROXIMATE TAP DRILL SIZES:

$$\text{Tap Drill Size} = \text{Outside Diameter} - \frac{(.75 \times 1.299)}{\text{No. threads per inch}}$$

**Example.** To find the correct tap drill size for a hole $\frac{5}{8}$-inch in diameter, 11 threads per inch, substitute in the formula given above.

$$\text{Tap Drill Size} = \tfrac{5}{8}'' - \frac{(.75 \times 1.299)}{11}$$

$$= .625 - \frac{(.75 \times 1.299)}{11}$$ For $\frac{5}{8}''$ substitute .625 the decimal equivalent for $\frac{5}{8}''$.

$= .625 - .0885$

$= .536$ (Decimal equivalent of tap drill size.)

$= \frac{17}{32}$ Find nearest decimal to .536 in Table 1 on coarse thread series. In another column you will find correct tap drill size to use, or $\frac{17}{32}$.

The above formula may be simplified as follows:
Since $\frac{3}{4}$ of 1.299 is approximately 1, the formula may be changed to read:





$$\text{Tap Drill Size} = \text{O.D.} - \frac{1}{N}$$

$$= \tfrac{5}{8}'' - \frac{1}{11}$$

$= .625 - .091$

$= .534$ or approximately $\frac{17}{32}$

For all practical purposes, the student can use this simpler formula

**Table 1. American National Standard Screw Thread and Recommended Tap Drill Sizes**

**FRACTIONAL SCREW SIZES**

Coarse Thread Series (N.C.) Formerly U.S. Standard

| Size of Screw Inches | Threads per inch | Major (Outside) Diameter of Screw | Tap Drill Size | Decimal Equivalent of Drill Inches |
|---|---|---|---|---|
| $\frac{1}{4}$ | 20 | .250 | 7 | .2010 |
| $\frac{5}{16}$ | 18 | .3125 | F | .2570 |
| $\frac{3}{8}$ | 16 | .375 | $\frac{5}{16}$ | .3125 |
| $\frac{7}{16}$ | 14 | .4375 | U | .3680 |
| $\frac{1}{2}$ | 13 | .500 | $\frac{27}{64}$ | .4219 |
| $\frac{9}{16}$ | 12 | .5625 | $\frac{31}{64}$ | .4843 |
| $\frac{5}{8}$ | 11 | .625 | $\frac{17}{32}$ | .5312 |
| $\frac{3}{4}$ | 10 | .750 | $\frac{21}{32}$ | .6562 |
| $\frac{7}{8}$ | 9 | .875 | $\frac{49}{64}$ | .7656 |
| 1 | 8 | 1.000 | $\frac{7}{8}$ | .875 |
| $1\frac{1}{8}$ | 7 | 1.125 | $\frac{63}{64}$ | .9843 |
| $1\frac{1}{4}$ | 7 | 1.250 | $1\frac{7}{64}$ | 1.1093 |

**MACHINE SCREW SIZES**

Coarse Thread Series (N.C.) Formerly U.S. Standard

| Size No. of Screw | Threads per inch | Major (Outside) Diameter of Screw | Tap Drill Size | Decimal Equivalent of Drill Inches |
|---|---|---|---|---|
| 1 | 64 | .073 | 53 | .0595 |
| 2 | 56 | .086 | 50 | .0700 |
| 3 | 48 | .099 | 47 | .0785 |
| 4 | 40 | .112 | 43 | .0890 |
| 5 | 40 | .125 | 38 | .1015 |
| 6 | 32 | .138 | 36 | .1065 |
| 8 | 32 | .164 | 29 | .1360 |
| 10 | 24 | .190 | 25 | .1495 |
| 12 | 24 | .216 | 16 | .1770 |

To find the diameter of number size screws multiply the screw size number by .013 and add .060.

### FRACTIONAL SCREW SIZES

Fine Thread Series (N.F.) Formerly S.A.E. Thread

| Size of Screw Inches | Threads per inch | Major (Outside) Diameter of Screw | Tap Drill Size | Decimal Equivalent of Drill |
|---|---|---|---|---|
| 1/4 | 28 | .250 | 3 | .2130 |
| 5/16 | 24 | .3125 | 1 | .2720 |
| 3/8 | 24 | .375 | Q | .3320 |
| 7/16 | 20 | .4375 | 25/64 | .3906 |
| 1/2 | 20 | .500 | 29/64 | .4531 |
| 9/16 | 18 | .5625 | .5062 | .5062 |
| 5/8 | 18 | .625 | .5687 | .5687 |
| 3/4 | 16 | .750 | 11/16 | .6875 |
| 7/8 | 14 | .875 | .8020 | .8020 |
| 1 | 14 | 1.000 | .9274 | .9274 |
| 1 1/8 | 12 | 1.125 | 1 3/64 | 1.0468 |
| 1 1/4 | 12 | 1.250 | 1 11/64 | 1.1718 |

### MACHINE SCREW SIZES

Fine Thread Series (N.F.) Formerly S.A.E. Thread

| Size of Screw Inches | Threads per inch | Major (Outside) Diameter of Screw | Tap Drill Size | Decimal Equivalent of Drill |
|---|---|---|---|---|
| 0 | 80 | .060 | 3/64 | .0469 |
| 1 | 72 | .073 | 53 | .0595 |
| 2 | 64 | .086 | 50 | .0700 |
| 3 | 56 | .099 | 45 | .0820 |
| 4 | 48 | .112 | 42 | .0935 |
| 5 | 44 | .125 | 37 | .1040 |
| 6 | 40 | .138 | 33 | .1130 |
| 8 | 36 | .164 | 29 | .1360 |
| 10 | 32 | .190 | 21 | .1590 |
| 12 | 28 | .216 | 14 | .1820 |

**HAND TAPPING.** The cutting of a thread with a tap is not a difficult operation but requires care in the manipulation. The tap does not need to be forced into the work, since the thread will draw it forward. The tapering of the tap has a two-fold effect. No one thread does all of the work in the removal of the metal; each succeeding thread removes a small amount until the full thread has entered the hole. The second effect is that, as in the case of a reamer, the





tap is easily entered and started. Care must always be exercised at this point of the work. The taper of the tap allows it to easily enter the hole and also makes it possible for it to enter at an angle so that the thread will not be at right angles to the hole. In the case of tapping a nut, it will usually be quite sufficient to set the tap by the eye. In finer classes of work, however, the tap should be set with a square. Start the tap into the hole and place a square on the surface beside it in two positions at right angles to each other and see that the tap stands parallel to the vertical blade.

**Checking the Work.** Check to make certain that the tap is entering the hole squarely, see Fig. 4. If it has not entered the hole

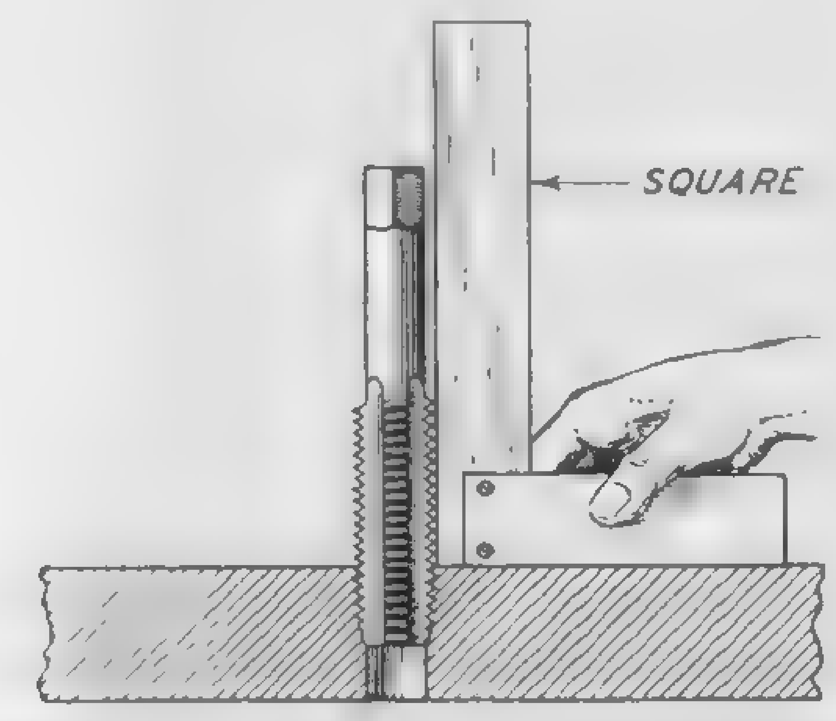



Fig. 4. Check Tap for Squareness with Work

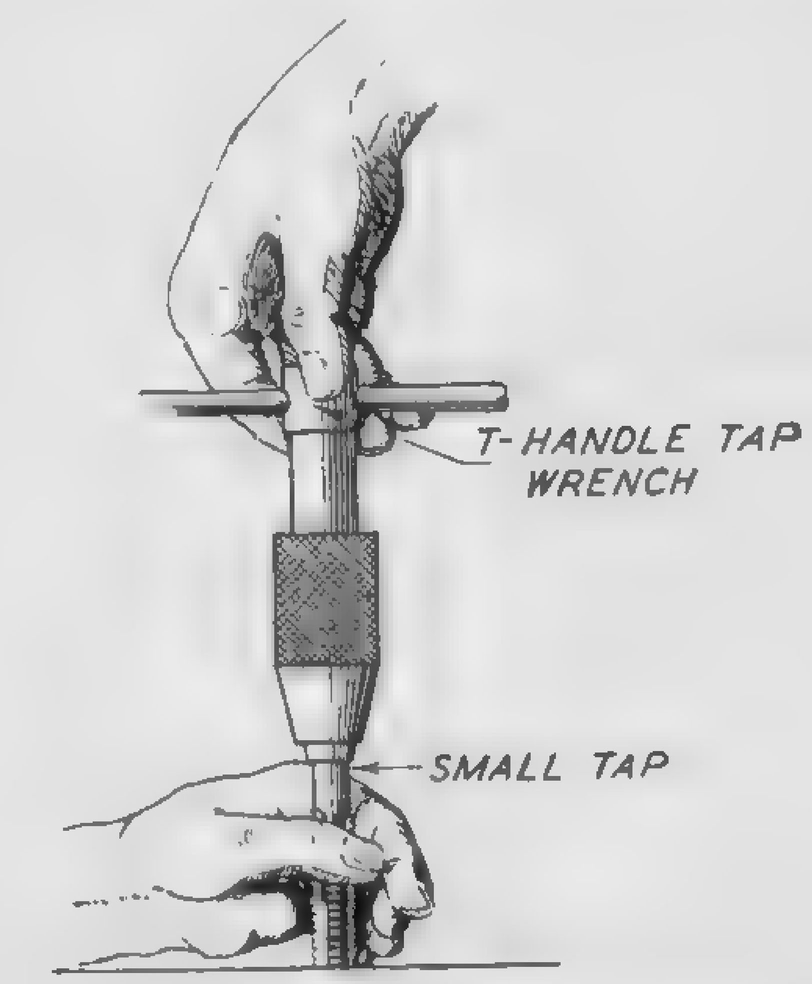



Fig. 5. Starting with a Small Tap

squarely, it is possible to remove it and re-start it with pressure applied in the proper direction.

**Starting the Tap.** When holes have been drilled that are to be tapped, a good way of setting the tap is to put a center in the drill spindle. Put the tap into the hole and bring this center into the center hole in the head of the tap; this will steady the latter while it is being started. Various types of handles or wrenches are used to turn the tap. Fig. 5 shows a **T**-handle tap wrench.

In using the tap, it is well to work it back and forth. Do this by turning the tap forward a part turn and then backward about half a turn. This allows the chips to work clear of the cutting edges, and the oil to cover them. In case of heavy work, it is possible to drive the tap with the drill spindle, but when thus driving a tap in

a machine; the backing up is impossible. Care must be taken not to press too heavily on one handle of the tap wrench; or to force the tap, because doing this is liable to break it in the hole.

**MACHINE TAPPING.** Machine tapping is best done by using a frictional tapholder, that is, one in which the friction is enough to cut the threads, but which will slip when the tap strikes the bottom of the hole. This will insure the hole being tapped to the bottom and avoid all danger of breaking the tap. To withdraw the tap, the machine is reversed, usually at a higher speed than used in tapping.

**LUBRICATION.** When tapping wrought iron and steel, a plentiful supply of lard oil should be used. On brass and cast iron the use of oil is unnecessary.

## THREAD DIES

Dies are used for cutting threads on bolts and other similar parts to be placed in holes which have been threaded by taps. The general rules given for the use of taps apply to dies. As the number

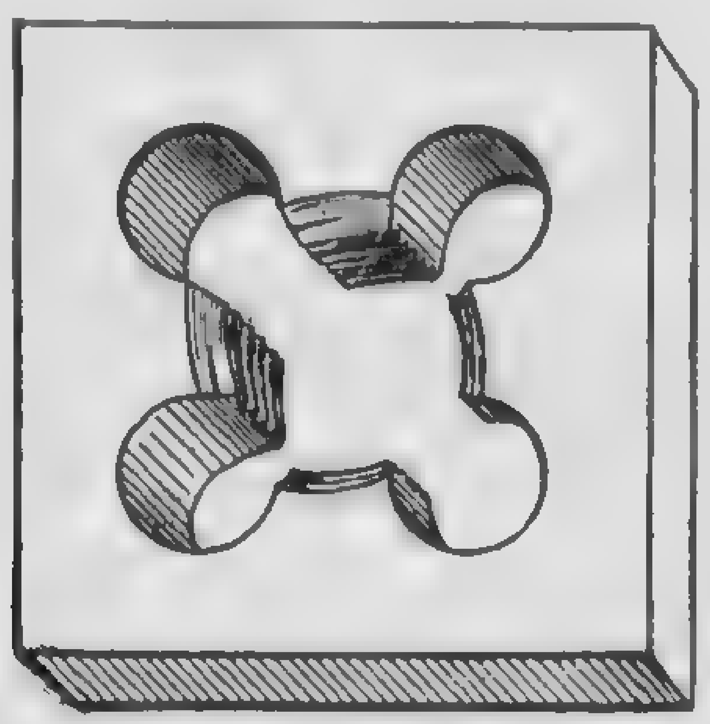


Fig. 6. Solid Threading Die

of threads in a die is much less than on a tap, and because the chips have a much freer exit, it is not as necessary to back up a die as it is a tap.

**SOLID DIES.** Dies for small work are usually made solid, as shown in Fig. 6. They are not adjustable and have a fixed size. They cannot be sharpened, but have an advantage in readily centering on the work. As the full thread is cut at one passage of the die, it takes considerable power to operate solid dies of large size. For this reason, hand-operated solid dies are seldom used above one-half inch. The holder or die stock shown in Fig. 7 has a guide





to hold the work at right angles to the die, but die stocks are often made without this convenience.

**SPLIT DIES.** The split form of die, generally known as the adjustable die, Fig. 8, can be easily resharpened, has unlimited adjustment for size, and cuts the thread by easy stages, as it were.

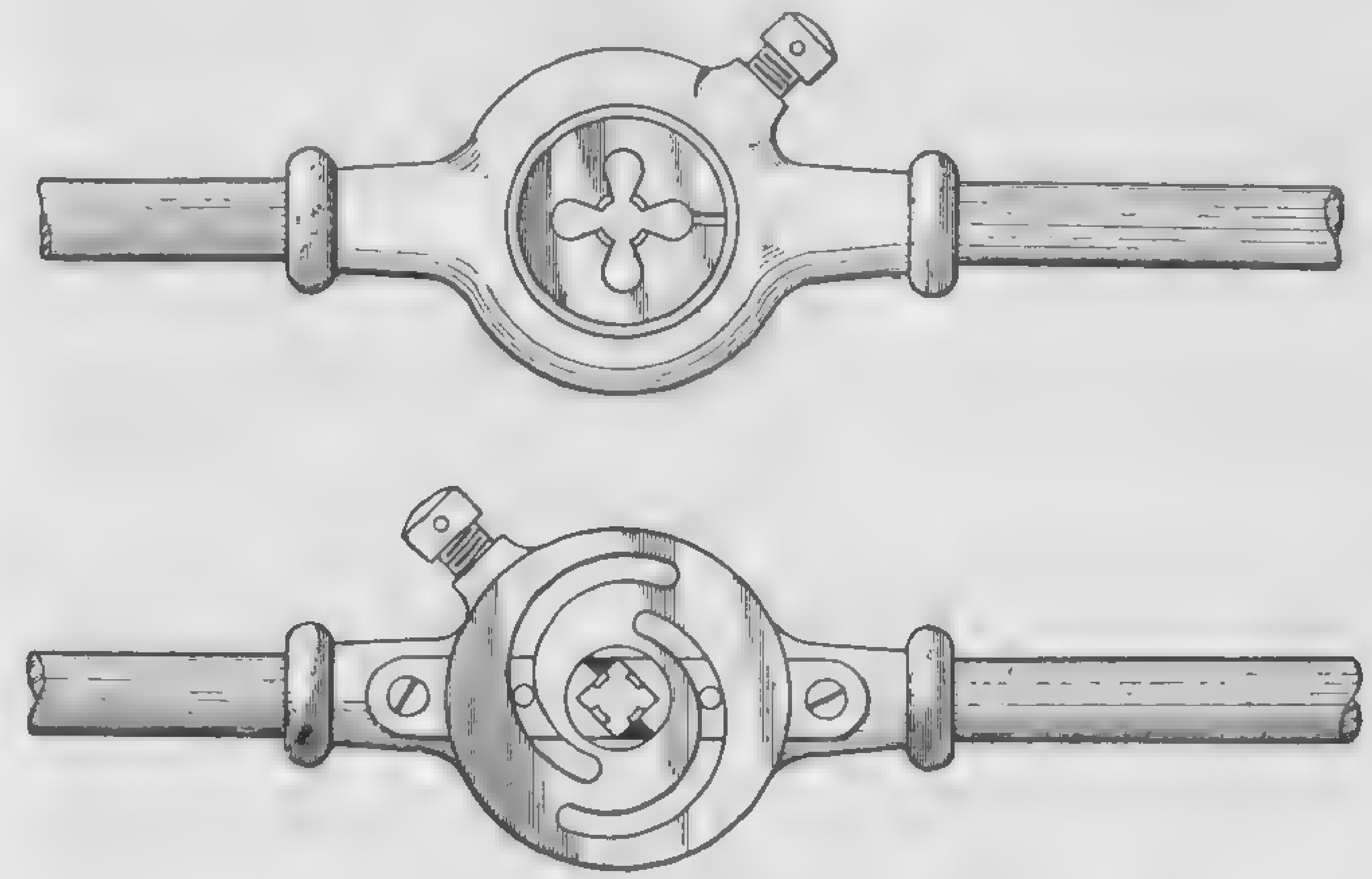
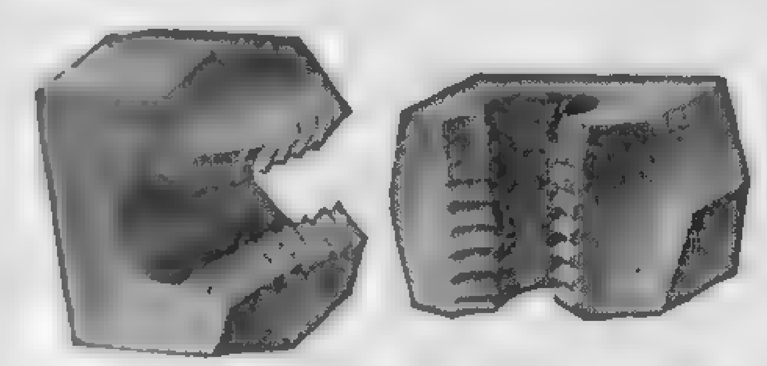


Fig. 7. Self-Centering Die



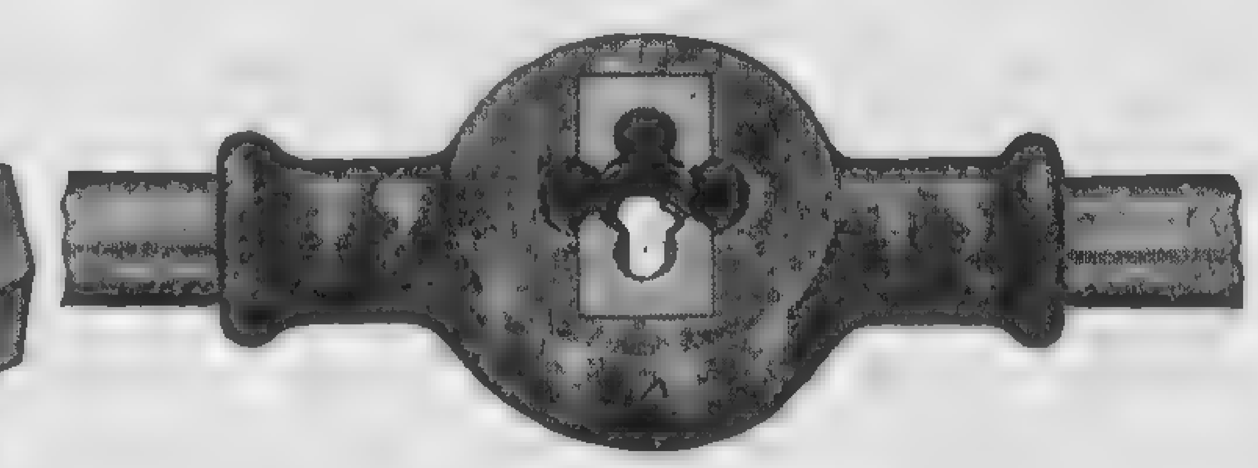


Fig. 8. Split or Adjustable Die Fig. 9. Screw Plate

*Courtesy of Greenfield Tap & Die Corp., Greenfield, Mass.*

It is made in sizes up to 2 inches and is for hand operation only. The holder for this form of die is called a screw plate, Fig. 9. These are not furnished with guides for the work.

**CUTTING PIPE THREADS.** Another common form of thread cutting is that done on pipe. The pipe thread is rounded slightly at top and bottom and is tapered at the rate of three-quarters of an inch per foot. The smaller dies are set in the holder, and the die stocks are provided with a ring which fits over the pipe and serves to hold it square with the die. This avoids the danger of cutting the thread at an angle with the pipe axis.

**CUTTING BOLT THREADS.** Bolt cutting is seldom done by hand, such work usually being performed on bolt-cutters. This is ordinarily the roughest and cheapest class of work, and the running of the bolt-cutter is often the first work to which the apprentice is assigned.

### HOW TO CUT A THREAD WITH A DIE

This procedure, generally followed in cutting threads by hand, is as follows:

1. Secure the work firmly in a vise.
2. See that the dies are held firmly in the die holder.
3. Drop some cutting oil on the chamfered end of the screw blank.
4. Place the chamfered side of the die squarely on the chamfered end of the screw blank.
5. Start turning the die slowly but firmly until the threads take hold.
6. After cutting several threads stop to determine that the die is square with the work.
7. If necessary adjust the die to cut threads to proper size.
8. Frequently, turn the die back to free the chip.

**Note:** While cutting use plenty of cutting oil. This prevents the threads from tearing.

### QUESTIONS

1. *Name the three kinds of taps in a tap set.*
2. *Tell when each tap is used.*
3. *How do you check to determine whether a tap is started square with the work?*
4. *Why does a tap break easily?*
5. *When tapping why is it advisable to turn backward frequently a part turn?*
6. *How can you prevent tearing a thread when cutting it?*
7. *What is a die?*
8. *What are the advantages and disadvantages of solid dies?*
9. *What are adjustable dies?*



# Linear Measurement

## THE DECIMAL DIVISIONS OF THE INCH

**WHY DECIMALS ARE USED.** It frequently happens that dimensions, instead of being given in halves, quarters, eighths, sixteenths, thirty-seconds and sixty-fourths of an inch, are given in decimals in cases where work is to be machined to very accurate dimensions with limits specified in thousandths or fractions of a thousandth of an inch. When decimal dimensions are to be approximated; that is, calculated roughly, as in roughing out stock, it is often necessary to determine the nearest sixty-fourth of a given decimal dimension.

**THE DECIMAL POINT.** The decimal point is the mark of distinction between whole numbers and parts of a whole number. A whole number is 1, which is called **Unity,** or a whole number may be 27, 391, 10, 482, etc. The unit of measurement commonly used in industrial shops is 1 inch.

When the drawings are made, the draftsman prints the dimensions of the job in inches or parts of an inch. When the decimal point is not used, the figure represents a certain number of whole inches, and the decimal point is assumed to be unnecessary.

**THE MEANING OF A DECIMAL.** Figures at the *left* of the decimal point are whole numbers. Figures at the *right* of the decimal point represent a dimension or an amount which is less than 1. There are 100 cents in every dollar. A dollar bill is spoken of as 1 dollar. Anything less than 1 dollar is called so many cents, since there is no coin less than 1 cent in the United States.

Twenty-five cents is written .25 which means 25/100 (twenty-five hundredths) of one dollar. Ten cents is written as .10 which means 10/100 (ten hundredths) of one dollar.

Zeros at the right of the decimal have no value when they stand alone. So the cents in a dollar, when less than 100, are expressed by figures at the right of the decimal point, called the decimal part of one

dollar. Decimals can never have a value of 1 or 100/100. The value is always less than 1 or 100/100.

**VALUES OF DECIMAL PLACES.** When there are figures at the right of the decimal point, these figures are said to occupy so many places and have certain values. The greater the number of decimal places occupied, the finer is the measurement. The values of five decimal places are given below. Three places are considered sufficient for all ordinary machine shop calculations. See Fig. 1. Four places are adequate for most precision work.

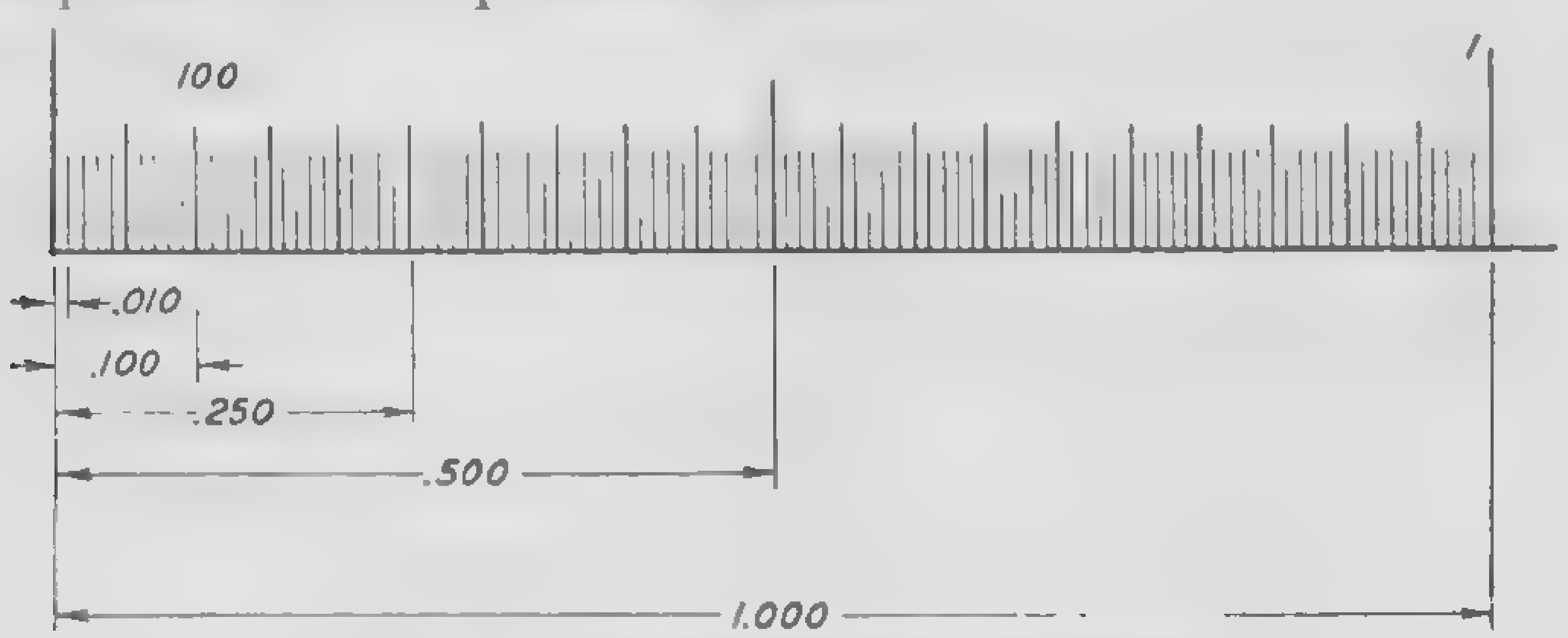



Fig. 1. An Inch Divided into Hundredths

| | | |
|---|---|---|
| .1 | means 1/10 | of an inch (one-tenth of an inch) |
| .01 | means 1/100 | of an inch (one one-hundredth of an inch) |
| .001 | means 1/1000 | of an inch (one one-thousandth of an inch) |
| .0001 | means 1/10,000 | of an inch (one ten-thousandth of an inch) |
| .00001 | means 1/100,000 | of an inch (one one-hundred-thousandth of an inch) |

**READING DECIMALS.** In practical shop work it is customary to read all dimensions in thousandths of an inch. Thus .5 would be read by the mechanic as five hundred-thousandths of an inch (.500). The addition of ciphers to the right of .5 does not change its value.

**PROBLEMS IN WRITING DECIMALS.** The following decimals (numbered 1 to 15) should be written out on a work sheet in order to familiarize yourself with ordinary shop expressions of decimal dimensions.

| | | |
|---|---|---|
| (1) 1.250 | (6) 1.394 | (11) .498 |
| (2) .673 | (7) .040 | (12) 2.437 |
| (3) 2.040 | (8) .008 | (13) 10.200 |
| (4) .937 | (9) 1.875 | (14) 2.725 |
| (5) .628 | (10) .125 | (15) 1.875 |

**DECIMAL EQUIVALENTS.** Writing 5 over 8 means 5 is to be divided by 8. In a common fraction this division is merely indicated. When the division is performed, the answer is the DECIMAL EQUIVALENT of the common fraction ⅝.





**Example.** To find the decimal equivalent of the fraction ⅝.

SOLUTION: Divide 5 by 8

```
    .625 answer
 8)5.000
   4 8
   ---
     20
     16
     --
      40
      40
      --
```

The answer, .625, is the decimal equivalent obtained by doing the indicated division. ⅝ equals .625.

**PROBLEMS IN FINDING DECIMAL EQUIVALENTS.** The decimal equivalents of the following common fractions should be worked out on a work sheet in order to familiarize yourself with the procedure used in finding decimal equivalents.

Find the decimal equivalents of the following 14 fractions:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (1) 1/8 | (3) 7/8 | (5) 5/16 | (7) 13/32 | (9) 15/64 | (11) 1/4 | (13) 7/16 | (15) 9/16 |
| (2) 23/64 | (4) 1/32 | (6) 1/64 | (8) 1/2 | (10) 19/64 | (12) 13/16 | (14) 3/32 | |

**Tables of Decimal Equivalents.** Tables of decimal equivalents are found in practically all the machine shop handbooks and textbooks. Charts which are convenient for making rapid calculations are also available to hang on the wall. These charts can usually be secured from tool manufacturers. You will find a table of decimal equivalents included with a group of tables in the back of this book for ready reference.

**READING MORE THAN THREE PLACES.** In cases where there are more than three decimal places used to express dimensions, the practical mechanic reads the number of thousandths and then the part of the thousandth which remains. Thus, .4375 would be read *four hundred thirty-seven and one-half thousandths.* The digit 5 in the fourth decimal place means 5/10 or ½ of the value indicated in the third decimal place. .005 would be read 5 thousandths, but .0005 would be read ½ thousandth or 5/10 of a thousandth.

## QUESTIONS

*1. What is a decimal point or what does the decimal point indicate?*

*2. State the values of the figures at the left and right of the decimal point.*

*3. What term is used to indicate the number of figures to the right of the decimal point?*

*4. What is the value of the fifth figure to the right of the decimal point?*

*5. What is the largest value that can be expressed with five figures at the right of the decimal point?*

*6. What is the nearest fraction, in 64ths, that will correspond to the following decimals? The fraction must not be less than the decimal.*

| | |
|---|---|
| (*a*) *.6250* | (*d*) *.8593* |
| (*b*) *.4257* | (*e*) *.7325* |
| (*c*) *.0468* | (*f*) *.9531* |

*7. Write out the shop expression for the following decimals:*

| | |
|---|---|
| (*a*) *1.875* | (*d*) *.1250* |
| (*b*) *.400* | (*e*) *.0002* |
| (*c*) *2.725* | |

*8. In what way is the value of a decimal changed if ciphers are added at the right?*

## MEASURING TOOLS

**STEEL RULE.** The standard steel rule, commonly called a *scale*, is in reality a graduated straightedge. A common form of steel rule is flat, varying from 1 to 48 inches in length, and carefully hardened and ground. The graduations in the better class of rules are cut with a dividing engine, although the lines may be etched on the surface with a fair degree of accuracy. The ends of flat rules are sometimes graduated, making what might be called a very short rule with a handle. Flat rules are sometimes graduated with metric divisions as fine as one millimeter, and from 5 centimeters to 1 meter in length.

What are known as narrow rules are obtainable from 4 to 36 inches and are of great convenience in certain cases. Besides these shapes, square rules are made in sizes from 3 to 6 inches in length, and the triangular form varies in length from 3 to 12 inches. Steel rules with the English system of graduation can be obtained with the inches divided in eighths, sixteenths, thirty-seconds, sixty-fourths; twelfths, twenty-fourths; tenths, twentieths, fiftieths, and hundredths. Special rules are made with graduations especially adapted to such uses as gear blank sizing, etc.

**Graduations.** Marks form the dividing lines between the spaces. The spaces are called graduations. The smallest graduation usually found on a mechanic's scale is one sixty-fourth part of one inch, expressed in figures as 1/64.

**Minimum Measurement Limits.** Some scales are divided into 10ths, 100ths, etc. Such graduations are convenient for special work, but they are not often used. When closer measurements are neces-





sary, the micrometer caliper is used. A split sixty-fourth is about as close as any mechanic may hope to measure with the ordinary steel scale.

**HOW TO READ THE STEEL RULE.** If we examine a scale closely, we will find that each graduation results from starting with one inch and dividing by 2 in Fig. 2, which gives us the ½-inch graduation.

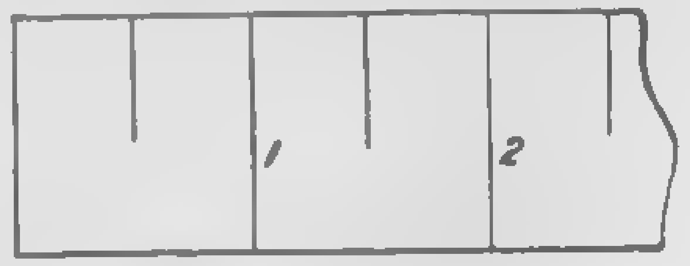



Fig. 2. Half-Inch Graduations

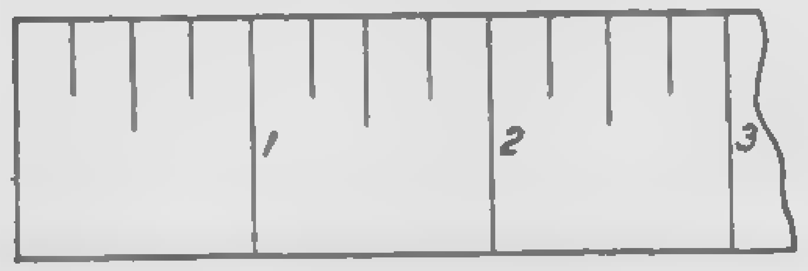



Fig. 3. Quarter-Inch Graduations

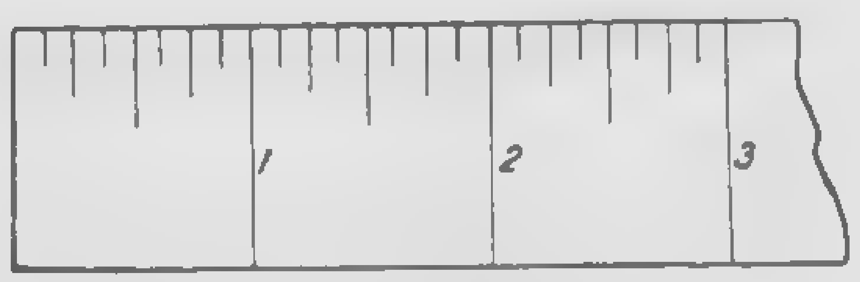



Fig. 4. One-Eighth Inch Graduations

But ½-inch graduations would not be small enough for measuring narrow edges so the ½-inch graduation is divided by 2, Fig. 3, which gives us the ¼-inch graduations.

There are still smaller sizes than ¼-inch to measure. The ¼-inch graduation is divided by 2, Fig. 4, which gives us the ⅛-inch graduations.

It should be quite clear, from the illustrations just given, that each small graduation is just half of the one before. Another plain fact is that the largest figure in the graduation is the number of that graduation contained in 1 inch. For example, count the 8ths in 1 inch and eight 8ths will be found.

The next largest graduation is just twice the size of the one before. For example, ¼ is just double ⅛. We already know ⅛ is half of ¼. Notice that if the bottom number in the fraction is *multiplied* by 2, the answer will be the next *smaller* graduation. If the

bottom number or denominator is *divided* by 2, the answer will be the next *larger* graduation. See Fig. 5.

**GETTING HALF OF A FRACTION.** All sizes less than 1 inch are fractions. Suppose half of $\frac{7}{8}$ is wanted. Disregard the 7 and multiply the bottom number, 8, by 2, which is 16. Put the 16 in place of the 8; the half of $\frac{7}{8}$ becomes $\frac{7}{16}$. Half of $\frac{7}{16}$ is found by multiplying 16 by 2, and the result is $\frac{7}{32}$.


Fig. 5. Fractional Divisions of an Inch

**ADDING FRACTIONAL DIVISIONS OF AN INCH.** The following procedure is recommended when you wish to add fractions of an inch.

**Example.** Assume that you wish to add the following parts of an inch: $\frac{1}{8}'' + \frac{5}{16}''$.

1. Find the decimal equivalent for each fraction. You can readily do this with the decimal equivalent table located with the other tables in the back of this book. $\frac{1}{8}'' = .125$

$\frac{5}{16}'' = .3125$

2. Add the decimal equivalents. Total .4375

3. If you wish the answer in fractions, locate the decimal in the table of decimal equivalents. To the left of the decimal, you will find the fractional equivalent. If you cannot find the exact decimal, find the decimal nearest to it and use the fraction for it. **Ans.** $\frac{7}{16}''$

### HOW TO USE THE SCALE

1. With the right hand lay the rule flat across the surface to be measured.
2. Extend the rule until its left end or a graduation is even with the left edge of the stock. Use the thumb nail to guide the rule.
3. Read the graduations on the rule from left to right.
4. Always measure stock at right angles. See Figs. 6, 7, and 8.





### QUESTIONS

1. *Read the measurements between the arrows in Fig. 9 at (A), (B), (C) and (D).*
2. *Name the several graduations on an ordinary mechanic's scale.*
3. *How many sixty-fourths of an inch are there in $\frac{5}{8}$ inch?*

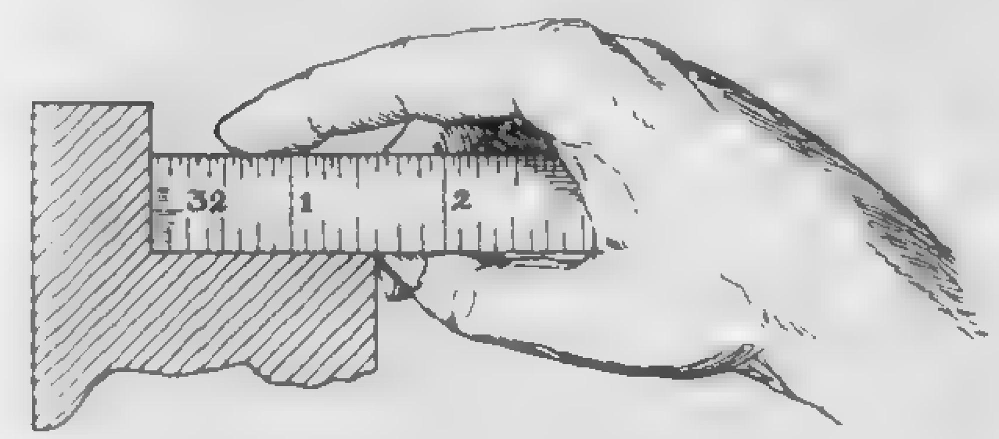


Fig. 6. Using a Rule

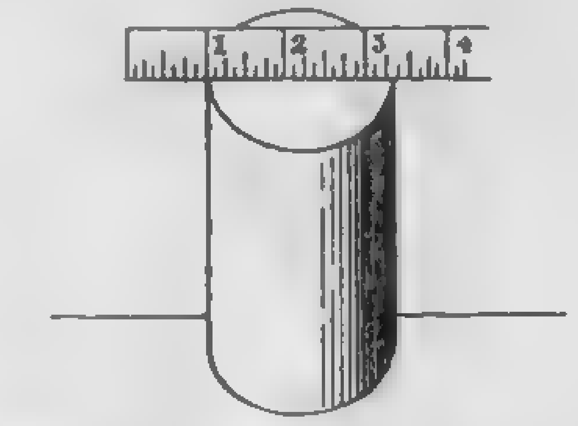


Fig. 7. Method for Measuring Work of Cylindrical Shape

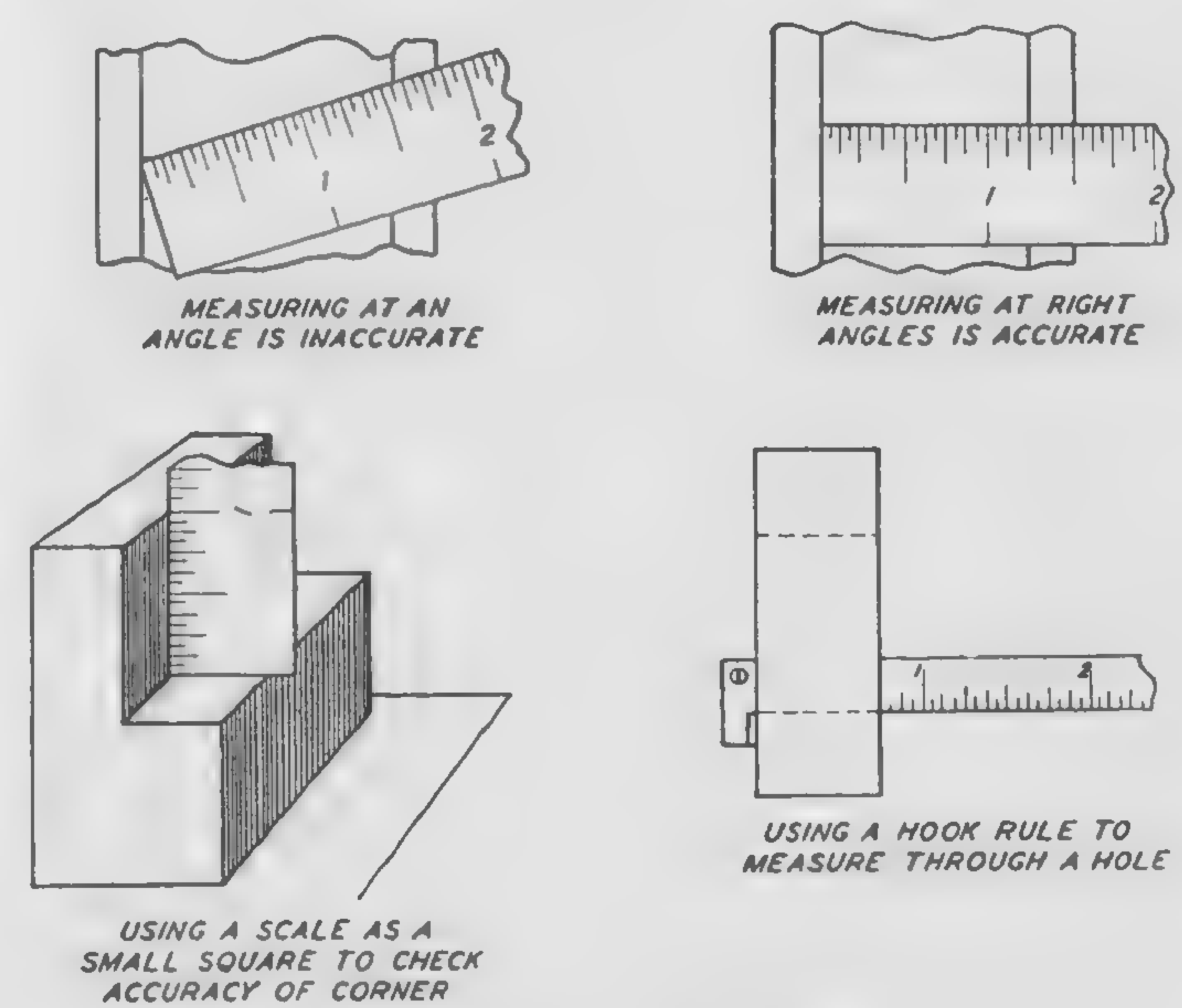



Fig. 8. Methods of Using a Steel Rule

4. *Should the numbers above the line, in a fractional dimension, be odd or even? Why?*
5. *What is the difference between $\frac{9}{32}''$ and $\frac{11}{64}''$?*
6. *Add the following:*

| | |
|---|---|
| (a) $\frac{7}{16} + \frac{3}{16}$ | (d) $\frac{5}{32} + \frac{1}{8}$ |
| (b) $\frac{19}{64} + \frac{1}{16}$ | (e) $\frac{13}{32} + \frac{1}{32}$ |
| (c) $\frac{5}{8} + \frac{9}{64}$ | (f) $1\frac{3}{64} + \frac{19}{32}$ |

7. *Subtract, or find the difference between the following:*

| | |
|---|---|
| (a) $1 - \frac{3}{16}$ | (e) $5\frac{1}{16} - \frac{13}{64}$ |
| (b) $1\frac{7}{32} - \frac{1}{8}$ | (f) $\frac{7}{8} - \frac{3}{8}$ |
| (c) $\frac{7}{16} - \frac{3}{32}$ | (g) $\frac{17}{64} - \frac{1}{32}$ |
| (d) $\frac{17}{32} - \frac{1}{4}$ | (h) $\frac{21}{32} - \frac{3}{64}$ |

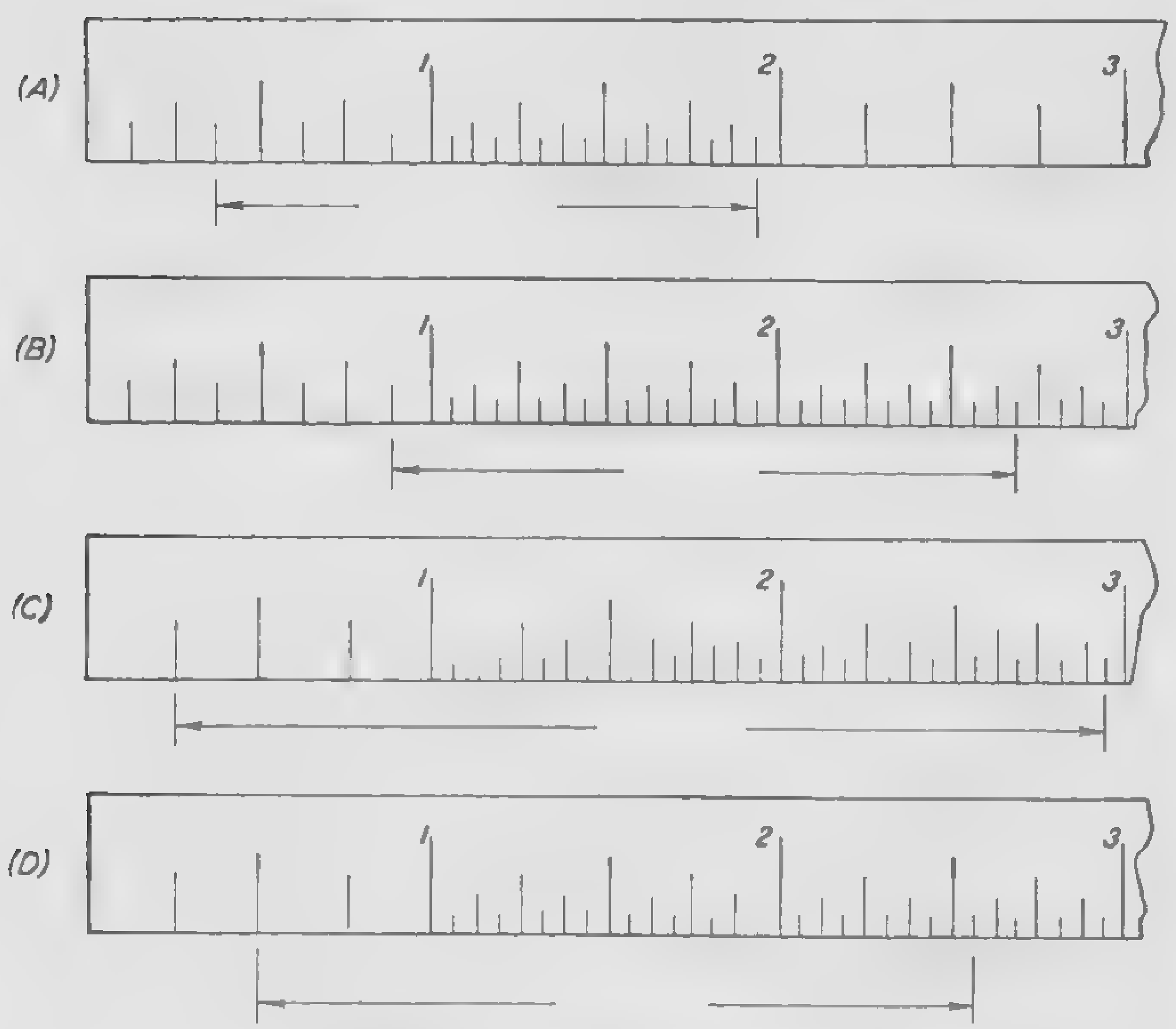



Fig. 9. Problems in Reading the Mechanic's Scale

## CALIPERS

**OUTSIDE AND INSIDE CALIPERS.** Instead of having straight legs with sharp points, like dividers, the legs on calipers are bent and have blunt points. As diameters and other dimensions of various pieces are to be measured both outside and inside, we have outside and inside calipers as shown in Fig. 10. The legs of outside calipers have a large curvature outward so that the calipers may be passed over cylinders of their greatest capacity.

Inside calipers are much like dividers in general appearance, the ends being bent outward slightly and the points rounded. The same styles of joints used in dividers are used in calipers, and the size of calipers is also designated by the distance fror the joint to the end of the leg. Spring calipers are made in sizes from $2\frac{1}{2}$ to 8 inches, while the other styles vary up to 24 inches.





**TRANSFER CALIPERS.** As it is sometimes necessary to make measurements behind shoulders and in chambered cavities where the ordinary calipers could not be removed after setting, it is necessary to have calipers so arranged that they may be set, changed to clear the obstruction, and then reset accurately in the first position.

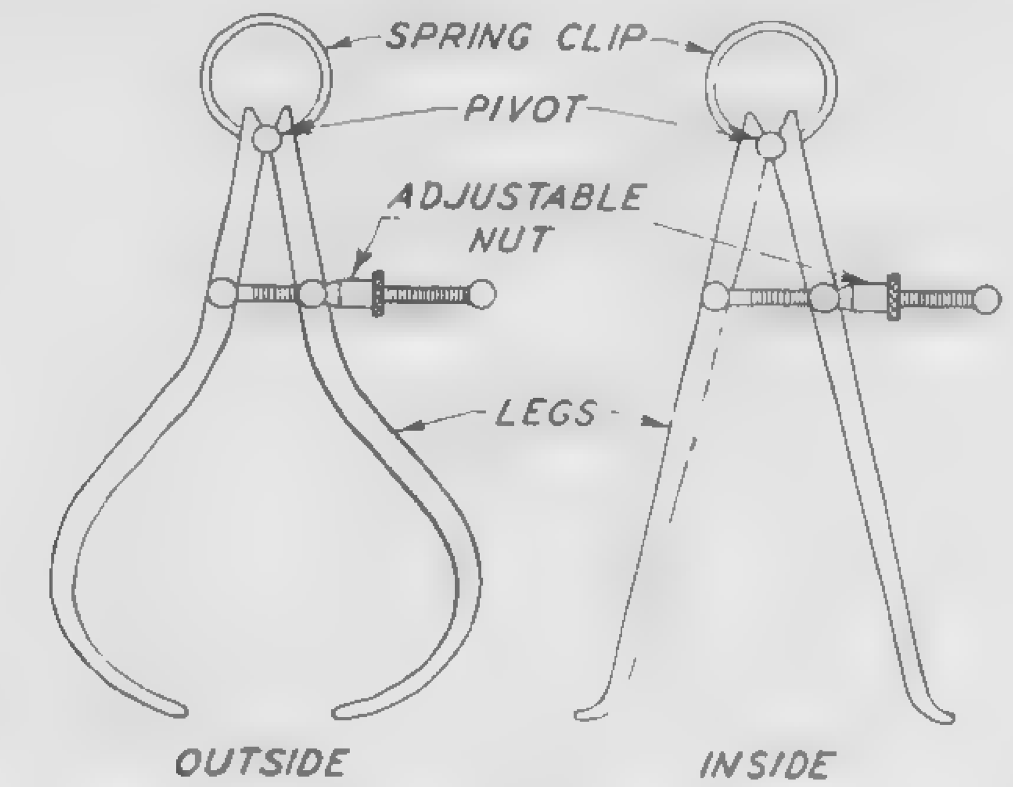



Fig. 10. Outside and Inside Calipers

Fig. 11. Brown & Sharpe Inside Transfer Calipers

Brown & Sharpe Outside Transfer Calipers

This is accomplished by transfer calipers, Fig. 11, in which one leg (the left in these illustrations) is clamped to a stub or false leg. After setting, this leg may be moved away from the stub, the calipers withdrawn, and the leg again placed in contact with the stub; the points will then be found to occupy the same position as when first set

**CARE OF CALIPERS.** Caliper legs are comparatively slender, spring easily, and care must be taken in using them to see that the contact with the object being tested is very light. It is an easy matter to spring calipers of common sizes as much as one-sixteenth of an inch unless a gentle touch is used in handling them. Calipers must never be forced over the work.

### HOW TO USE OUTSIDE CALIPERS TO MEASURE WORK

1. Hold the calipers lightly in the right hand. The forefinger and thumb should grasp the adjusting nut.

2. Adjust the caliper so that it will just slide over the work by its own weight, as in Fig. 12.

3. Without disturbing the setting, remove the calipers from the work.

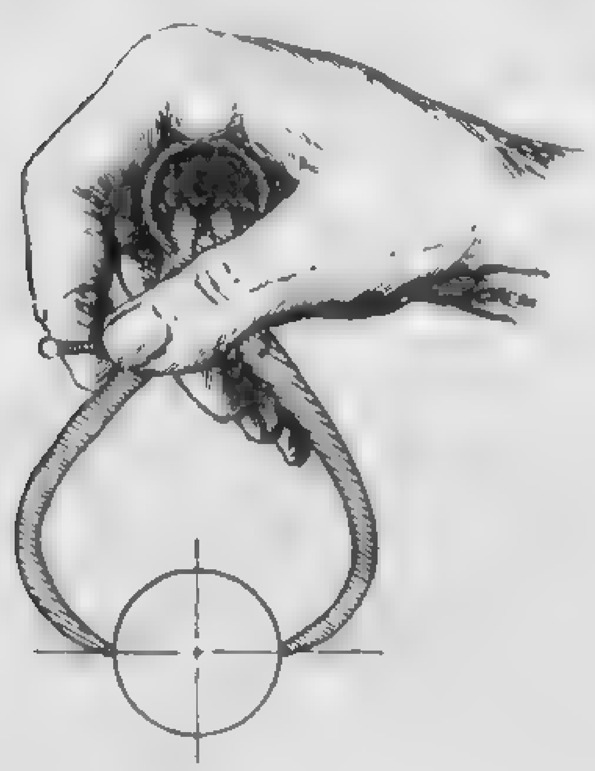


Fig. 12. Setting the Calipers

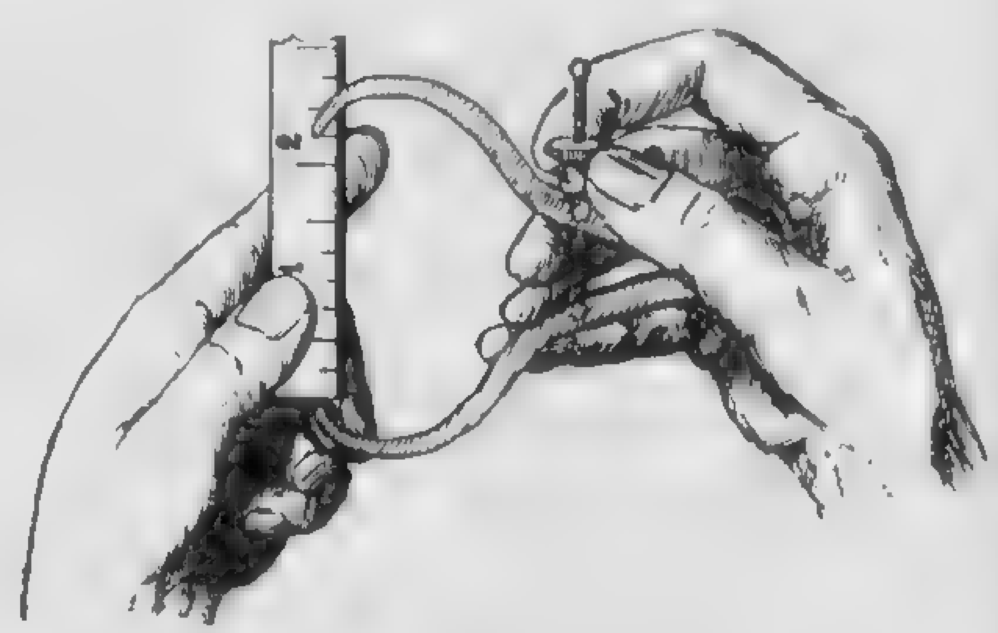


Fig. 13. Reading an Outside Caliper Setting

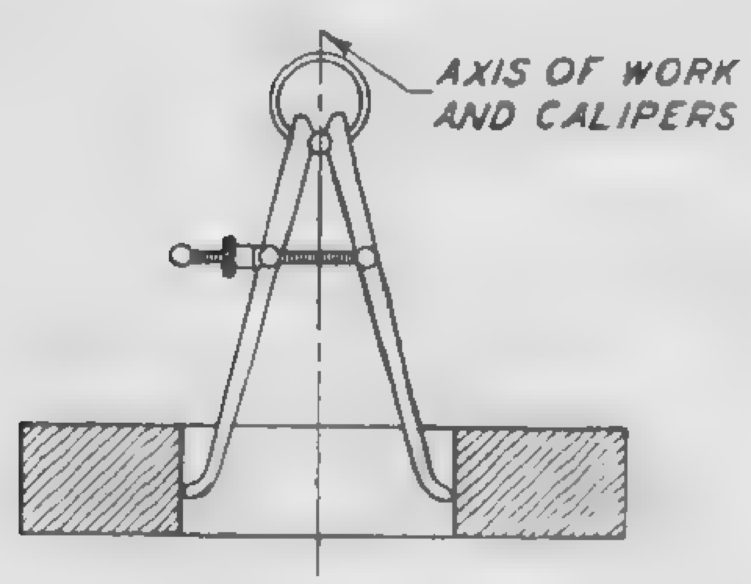



Fig. 14. Correct Way to Use Inside Calipers

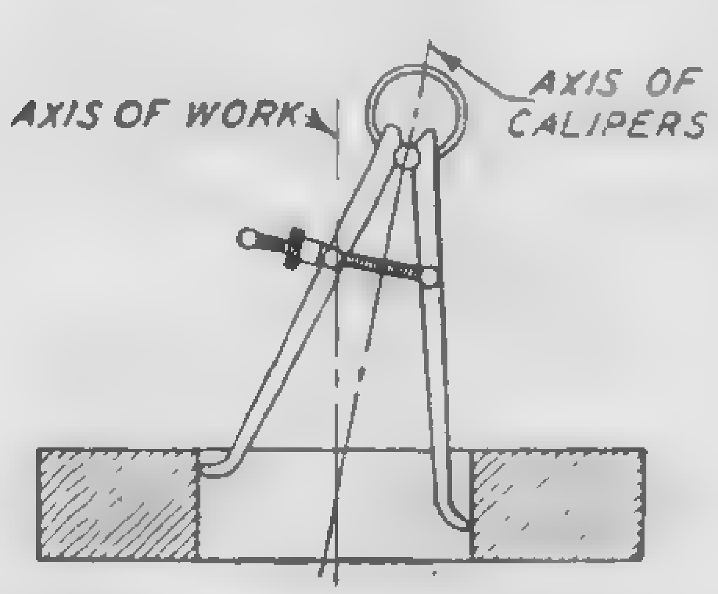



Fig. 15. Incorrect Way to Use Inside Calipers

4. Measure the distance between the caliper legs. Do this while holding the rule in the left hand.

5. Place one of the legs at the end of the rule. Place the other leg on the graduated edge of the rule but in line with the other leg and square with the edge of the scale, as shown in Fig. 13.

6. Read the measurement.

**Note:** When setting the caliper make sure that it is square with the work.





### HOW TO USE INSIDE CALIPERS TO MEASURE WORK

1. Hold the calipers lightly in the right hand.

2. Rest one leg of the caliper slightly inside the edge of the work to be measured. Make sure that the caliper legs are square with the work.

In measuring circular work no side motion of the caliper should be possible. See Figs. 14 and 15 for correct and incorrect way to use inside calipers.

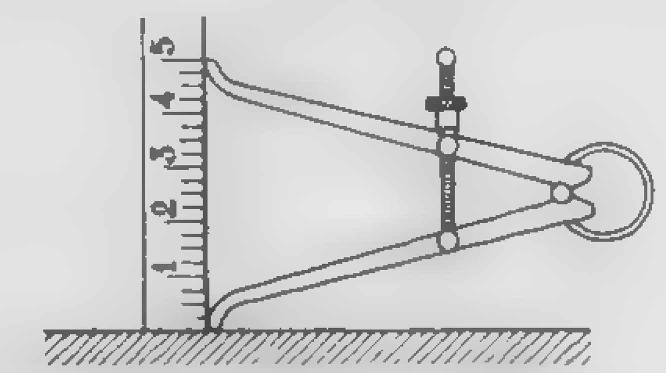


Fig. 16. Reading Setting of an Inside Caliper

3. Place one end of a steel rule on a horizontal surface. Hold the caliper legs on the surface against the rule, as shown in Fig. 16. Next, read the dimension on the rule.

## MICROMETERS

For measurements which are required to be more accurate than can be obtained by the preceding forms of calipering devices, the micrometer caliper, Fig. 17, is used. This is commonly called the micrometer or "mike." The accuracy of its measurements is determined, not by direct setting to two lines, but by finely dividing the pitch of the measuring screw (which opens and closes the micrometer) and furnishing means for reading these subdivisions of the pitch. The micrometer is a registering as well as an indicating caliper, and thus serves the purpose of a common caliper in combination with a rule, but with a much greater degree of accuracy.

**KINDS.** Micrometers are made in various shapes and sizes, depending upon the purpose for which they are to be used. The ones made for use in the machine shop may be classified roughly as outside, inside, and depth micrometers. Another one that is used a great deal is the screw thread micrometer, but this is really an outside micrometer. Space does not permit a description of all these various kinds, but any one interested is referred to any small tool catalog for this information.

**CONSTRUCTION.** In order to learn how to read a micrometer, the beginner must know something of its construction. A thorough understanding of the inside construction will help in understanding

how it should be used. The principle underlying the construction of the micrometer is that of recording the advance of a screw for any

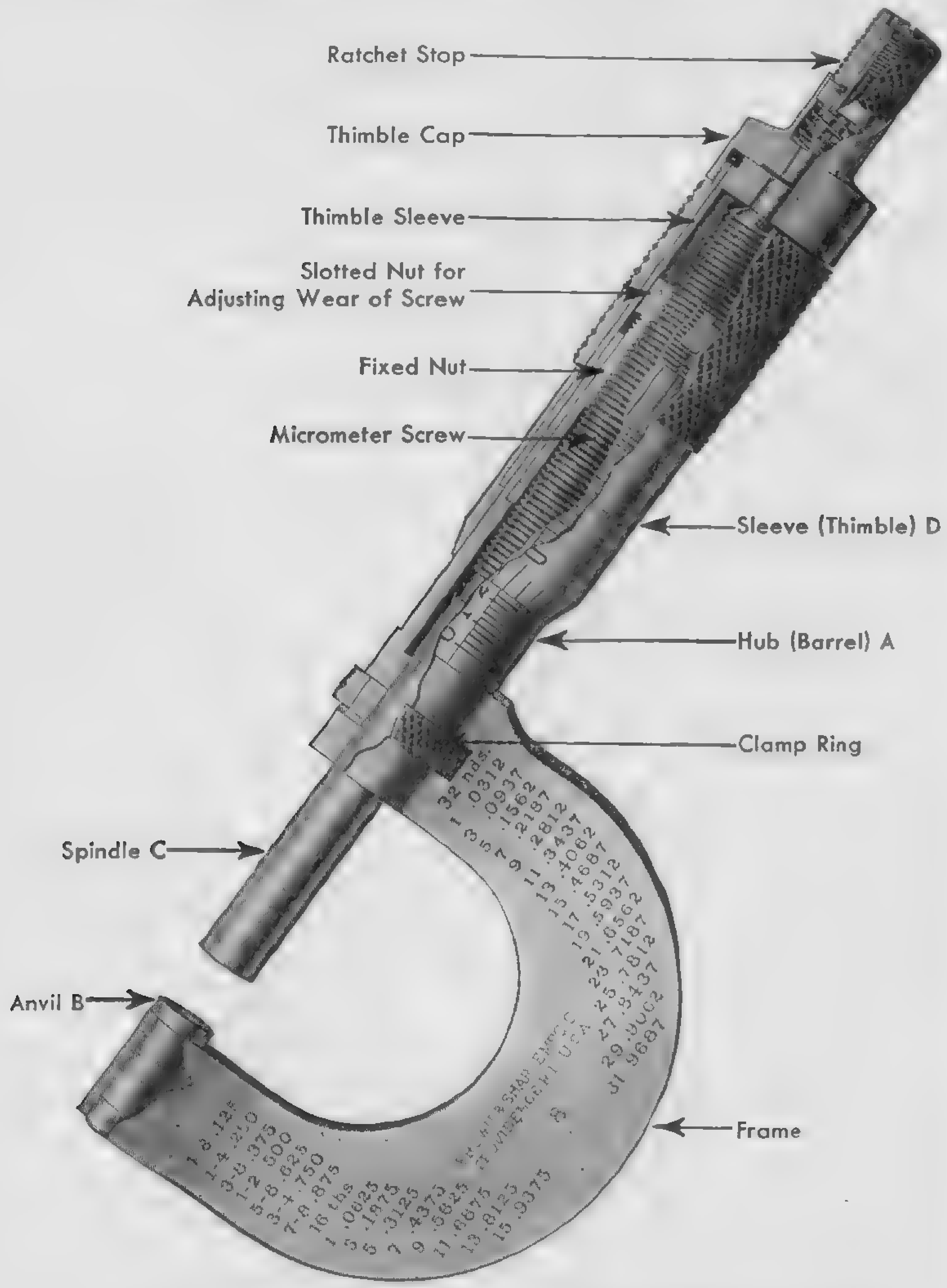



**Fig. 17. Cutaway View Showing Construction of Micrometer Caliper**
*Courtesy of Brown & Sharpe Mfg. Co., Providence, R.I.*

number of turns, or for any part of a turn. Fig. 17, which is a sectional view of a 1-inch micrometer, shows that the spindle $C$ is threaded at the upper end where it passes through a thread which is cut on the inside of the hub $A$. This hub does not rotate. The sleeve





$D$ is fastened to the spindle at the top so that it turns with the spindle. This sleeve is chamfered or beveled at the end next to the hub and the circumference is divided or graduated into 25 equal divisions. Each fifth graduation is marked 0, 5, 10, 15, and 20. These graduation marks are used for measuring any part of a turn of the sleeve and, therefore, the movement of the spindle.

The hub $A$ is marked with a line which is parallel with its center line, known as the "index line." This line is used in connection with the circular graduations on the sleeve. The hub is also marked over a space 1 inch long with a series of lines at right angles to the index line. These lines are of the same pitch as the threads of the spindle. Numerals from 1 to 10 are stamped opposite every fourth one of these marks. The 1-inch line has 10 numerals and 40 spaces marked on the hub.

Since the pitch (number of threads to the inch) of the thread on the screw is 40, then the spindle will advance one-fortieth of one inch in one turn. Now one-fortieth of one inch is 25 thousandths, which is commonly written in decimal form, .025. There are 25 graduations on the bottom of the sleeve, and it will readily be seen that if the spindle is turned through one of these graduations, it will advance one-thousandth, (.001) inch. It will also be seen by referring to Fig. 17 that the sleeve in one turn will advance a distance equal to the distance between two of the marks (.025 inch) which are stamped on the hub at right angles to the index line.

**PITCH.** Some micrometer screws have a different pitch. For example: if the pitch of the measuring screw is one-hundredth of an inch, there should be 10 divisions on the thimble, if one-fiftieth of an inch, 20 divisions; if one-fortieth of an inch, 25 divisions; if one twenty-fifth of an inch, 40 divisions. Measuring screws having a pitch of one-fortieth of an inch are usually used with every fourth division on the barrel lengthened and numbered to indicate tenths of an inch.

The micrometer will indicate the exact measurement so that the user will know whether the work is too large or too small and the amount by which it differs from the desired measurement. This is a great improvement over the rigid form of calipers, and enables the workman to judge more accurately the progress of the work. By turning the clamp ring, Fig. 17, the micrometer spindle may be clamped at any setting.

The range of motion of the measuring screw is usually limited to 1 inch, but various devices give the micrometer caliper a larger range of action. Micrometers may now be purchased in combinations or sets, with a range from zero to 20 inches.

**INSIDE MEASUREMENTS.** The application of the micrometer principle to inside measurements is now in general use. It is easy to arrange, and makes a very simple instrument, as shown in Fig. 18.

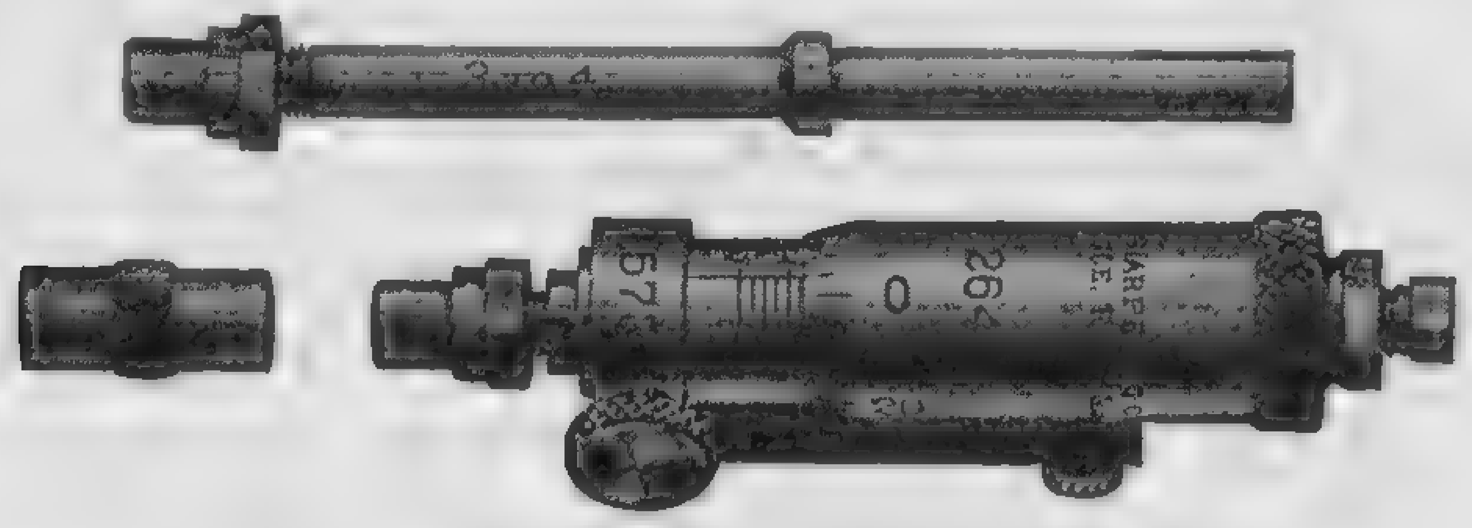


**Fig. 18. Inside Micrometer with Extension Rod**
*Courtesy of Brown & Sharpe Mfg. Co., Providence, R.I.*

It consists of an ordinary micrometer head, except that the outer end of the sleeve carries a contact point, attached to a measuring rod which may be of any length. The shortest distance that can be measured with this device is about 2 inches, but there is hardly any limit in length, as the rigidity of the rod is easily provided for. It is evident that such rigidity is harder to obtain in the curved shape necessary for outside measurement and thus limits this form to about 20 inches. The contact points in the outside type of micrometers are parallel plane surfaces, while in the inside form they are rounded points of small radius. Outside micrometers are provided with contact points of varying forms for measuring paper, threads, walls of tubes, etc. Figs. 19 and 20 illustrate methods of measuring large and small diameters with inside micrometers.

### HOW TO READ THE MICROMETER

1. On the barrel, the lines marked 1, 2, 3, etc., indicate measurements of .100″, .200″, .300″, etc., as in Fig. 21.

2. Each section between the divisions 1, 2, 3, etc. (tenth-inch divisions) is divided into four equal parts. Each of these divisions is equal to .025 of an inch, as shown in Fig. 22.

Turning the thimble one complete revolution from 0 to 0, moves the thimble exactly one of these .025 divisions, as shown in Fig. 23.

3. The beveled edge of the thimble is divided into twenty-five equal parts, Fig. 24. Each of these divisions on the thimble represents .001″ (one thousandth of an inch), Fig. 25. These divisions are numbered every five spaces 0, 5, 10, 15,





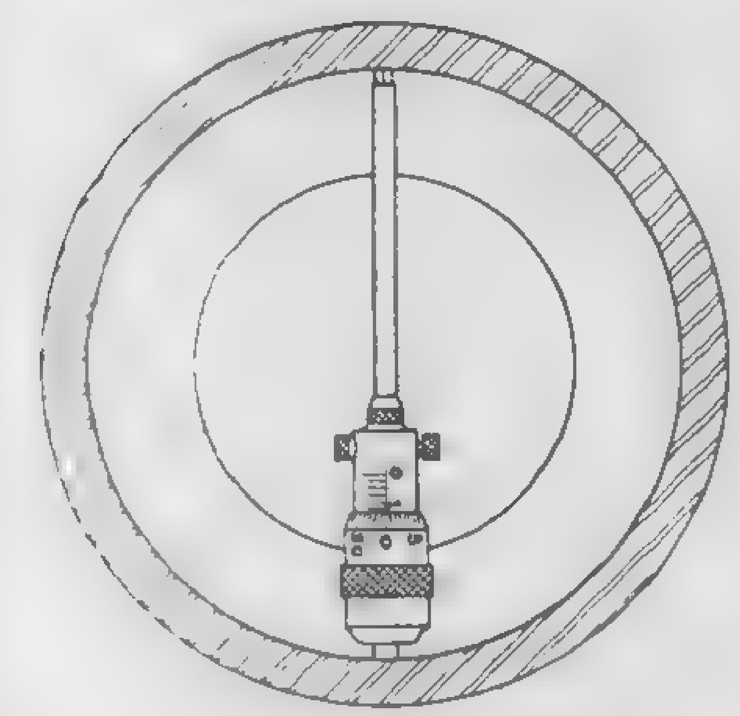


**Fig. 19. Measuring Large Diameters with Inside Micrometer**

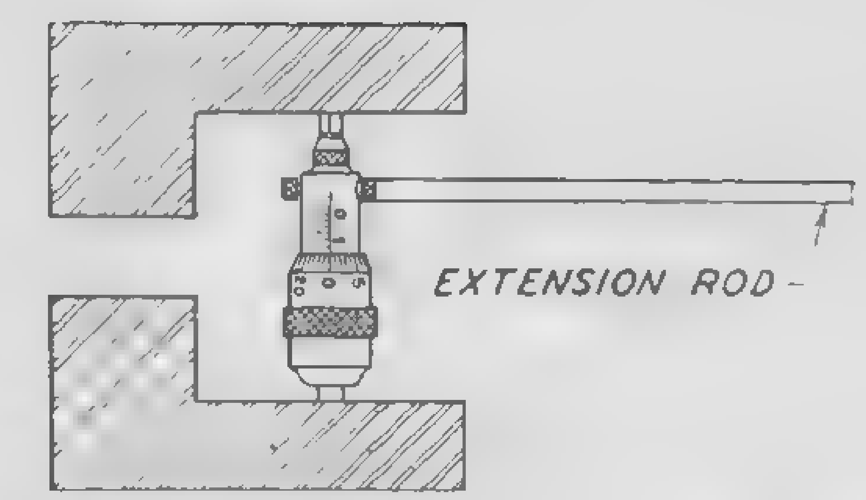



**Fig. 20. Measuring Small Diameters with Inside Micrometer**

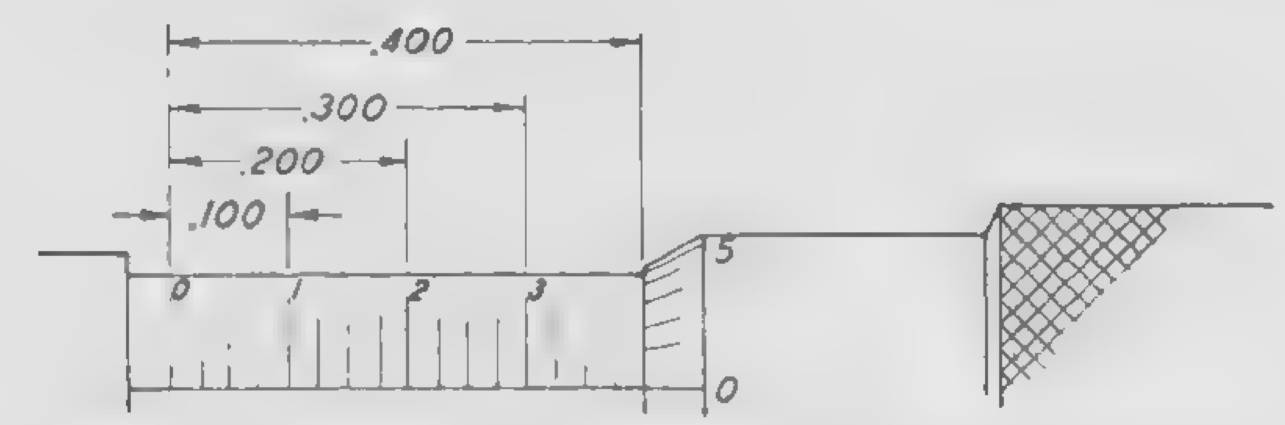



**Fig. 21. Readings of .100″, .200″, .300″, and .400″**

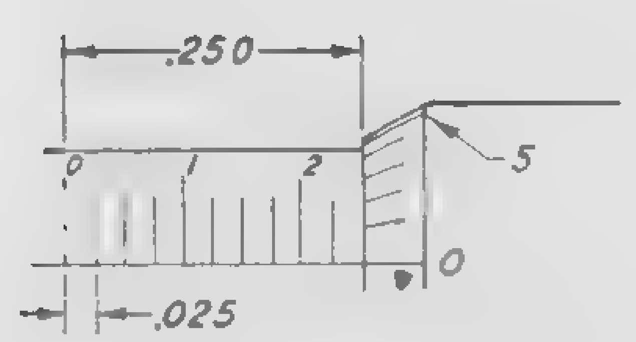



**Fig. 22. Divisions of .025″ Between Tenths**

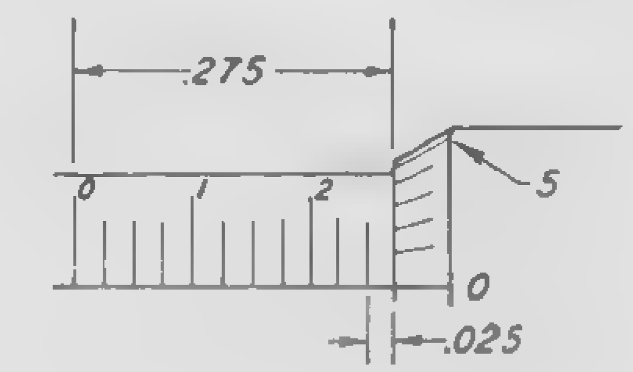



**Fig. 23. Each Complete Revolution of Thimble Turns Spindle .025″**

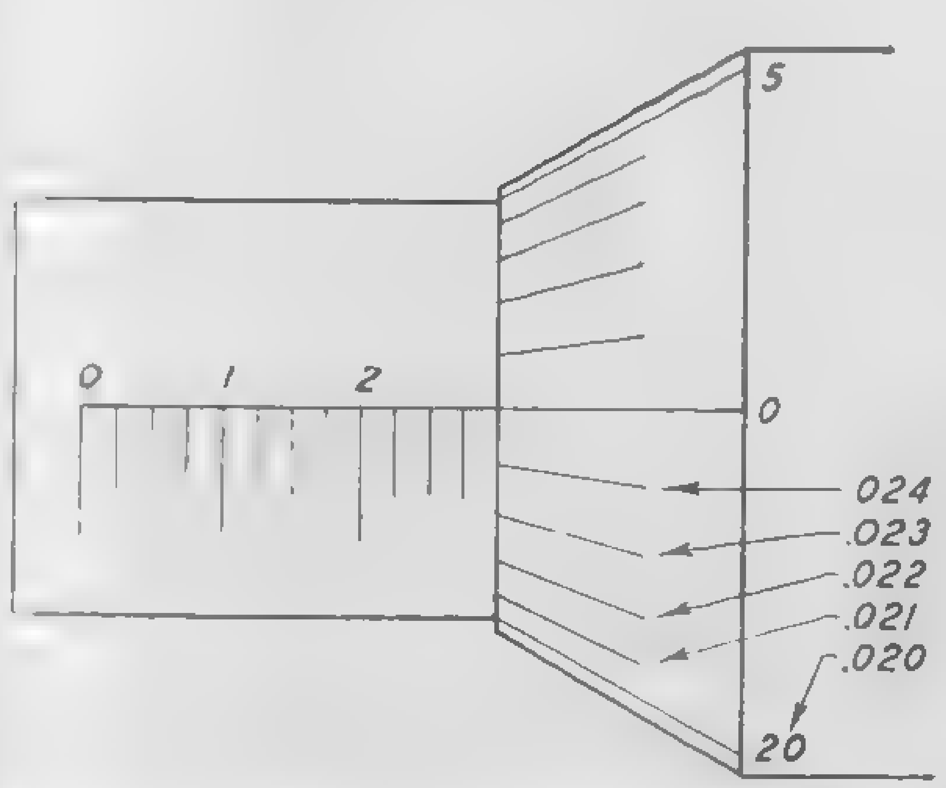



**Fig. 24. Thimble Has Twenty-Five Divisions**

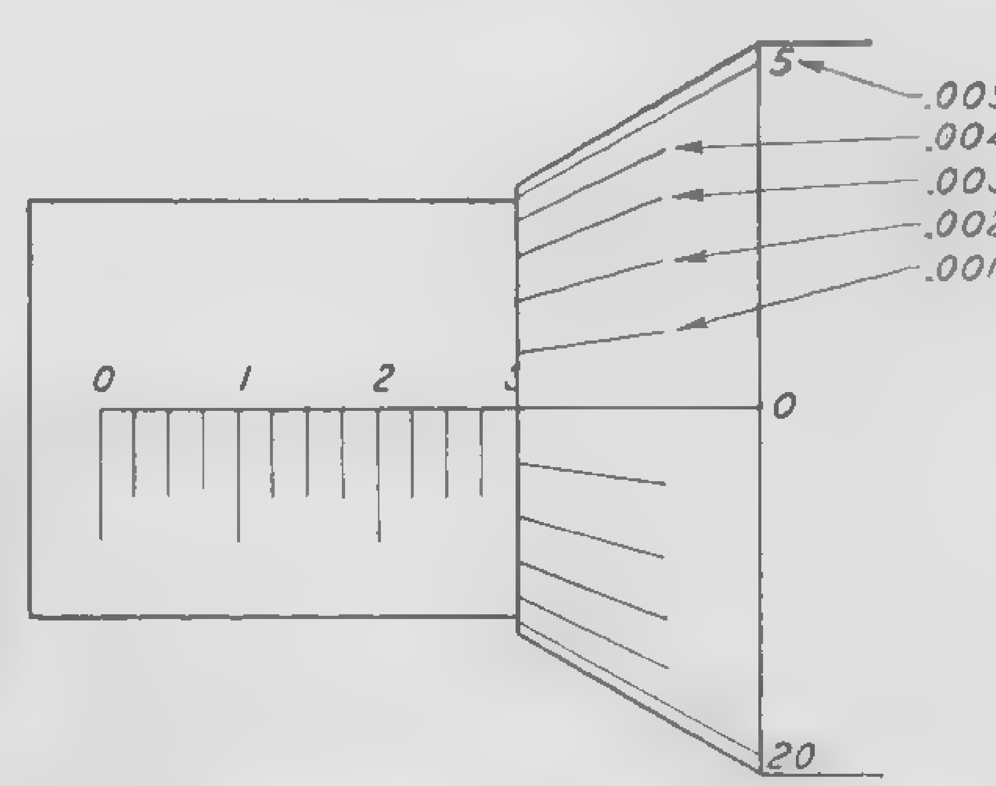



**Fig. 25. Each Division on Thimble Equals .001″**

20. When 25 of these spaces have passed the horizontal line on the barrel, the spindle has made one complete revolution and has moved .025″. At this point the spindle reads again at 0.

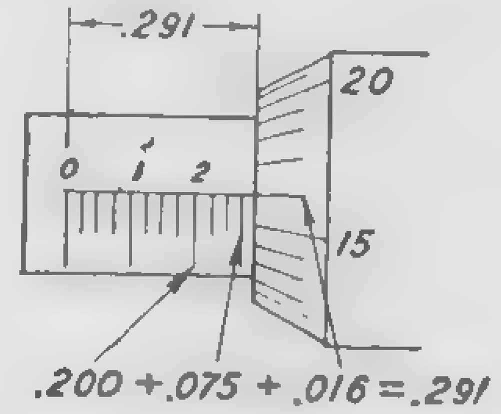



Fig. 26. Method for Reading the Micrometer

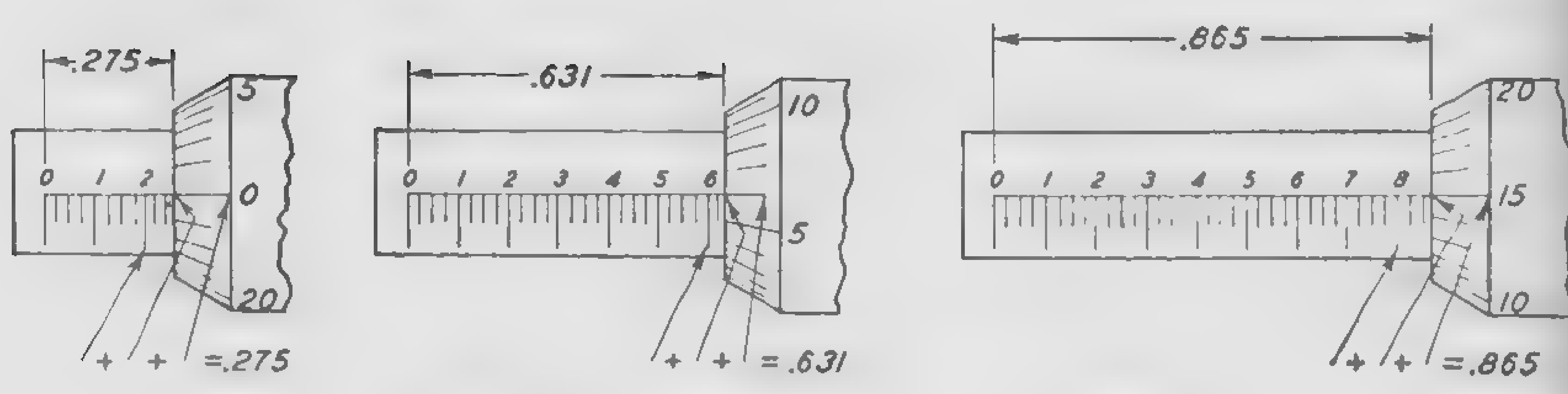



Fig. 27. Problems in Reading the Micrometer

4. To make a final reading, go through steps 1, 2, and 3 given above and add together each of these readings, see Figs. 26 and 27. Adding these readings together will give you the final reading.

**READING A TEN-THOUSANDTHS MICROMETER.** Readings in ten-thousandths of an inch are obtained by the use of a Vernier, so named from Pierre Vernier, who invented the device in 1631. As

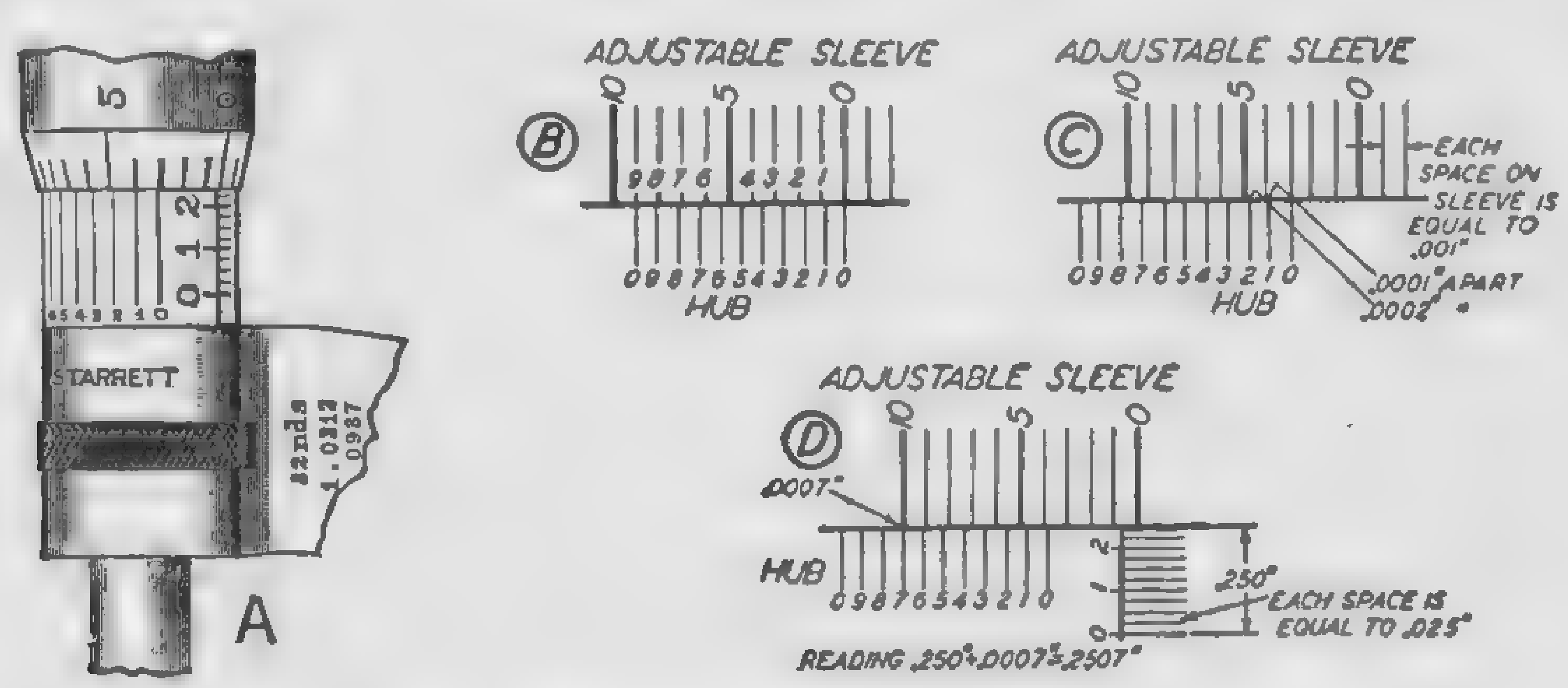



Fig. 28. How to Read the Micrometer Caliper with a Vernier

applied to a micrometer this consists of ten divisions on the circumference of the hub, which occupy the same space as nine circular divisions of adjustable sleeve, as shown in sketch *B*, Fig. 28. The differ-





ence between the width of one of the ten spaces on the hub and one of the nine spaces on the sleeve is, therefore, one-tenth of a space on the sleeve. In sketch *C* the third line from 0 on the sleeve coincides with the first line on the hub. The next two lines on sleeve and hub do not coincide by one-tenth of a space on sleeve; the next two, marked 5 and 2, are two-tenths (.2) apart, and so on. In opening the tool, by turning the sleeve to the left, each space on the sleeve represents an opening of one-thousandth of an inch. If, therefore, the sleeve is turned so that the lines marked 5 and 2 coincide, the caliper will be opened two-tenths of one thousandth or two ten-thousandths. Turning the sleeve further, until the line 10 coincides with the line 7 on the hub as in sketch *D*, the caliper has been opened seven ten-thousandths, and the reading of the tool is .2507.

To read a ten-thousandths caliper, first note the thousandths as in the ordinary caliper, then observe the line on the hub which coincides with a line on the sleeve. If it is the second line, marked 1, that coincides, add one ten-thousandth (.0001); if it is the third line, marked 2, add two ten-thousandths (.0002); and so on.

## HOW TO USE THE MICROMETER (FIG. 29)

**THE RATCHET STOP OF A MICROMETER.** Many micrometers have a ratchet stop at the end of the thimble or barrel. Use this when adjusting the measuring point against the work. When the point bears lightly against the work, the ratchet stop will slip, thus preventing excessive pressure against the measuring point. The ratchet stop will click when it starts to slip. This device permits you to secure a uniform pressure; consequently, uniform readings are possible.

**ADJUSTING THE MICROMETER TO THE WORK.** A micrometer should not be set at the size required and pushed over the work, but should first be opened, then screwed down on the object to be measured until the end of the spindle and the anvil are in contact with the work. The proper degree of pressure to be applied to the screw is acquired only after extended practice; however, the ratchet stop will control this if used.

All adjustments and readings must be taken across the center of the work. The micrometer may be moved carefully back and forth over the work to find the maximum diameter.

### SUGGESTIONS ON USING THE MICROMETER (FIG. 29)

1. In using a one-inch micrometer, hold it in the right hand with the frame in the palm and the thimble between the thumb and forefinger for turning.

In using a 1-inch micrometer for small work, hold the tool in one hand, turning the thimble with the same hand, as shown. This permits freedom of the other hand for holding the work. In measuring larger or stationary work, the frame should be held securely in one hand while the other hand turns the thimble.

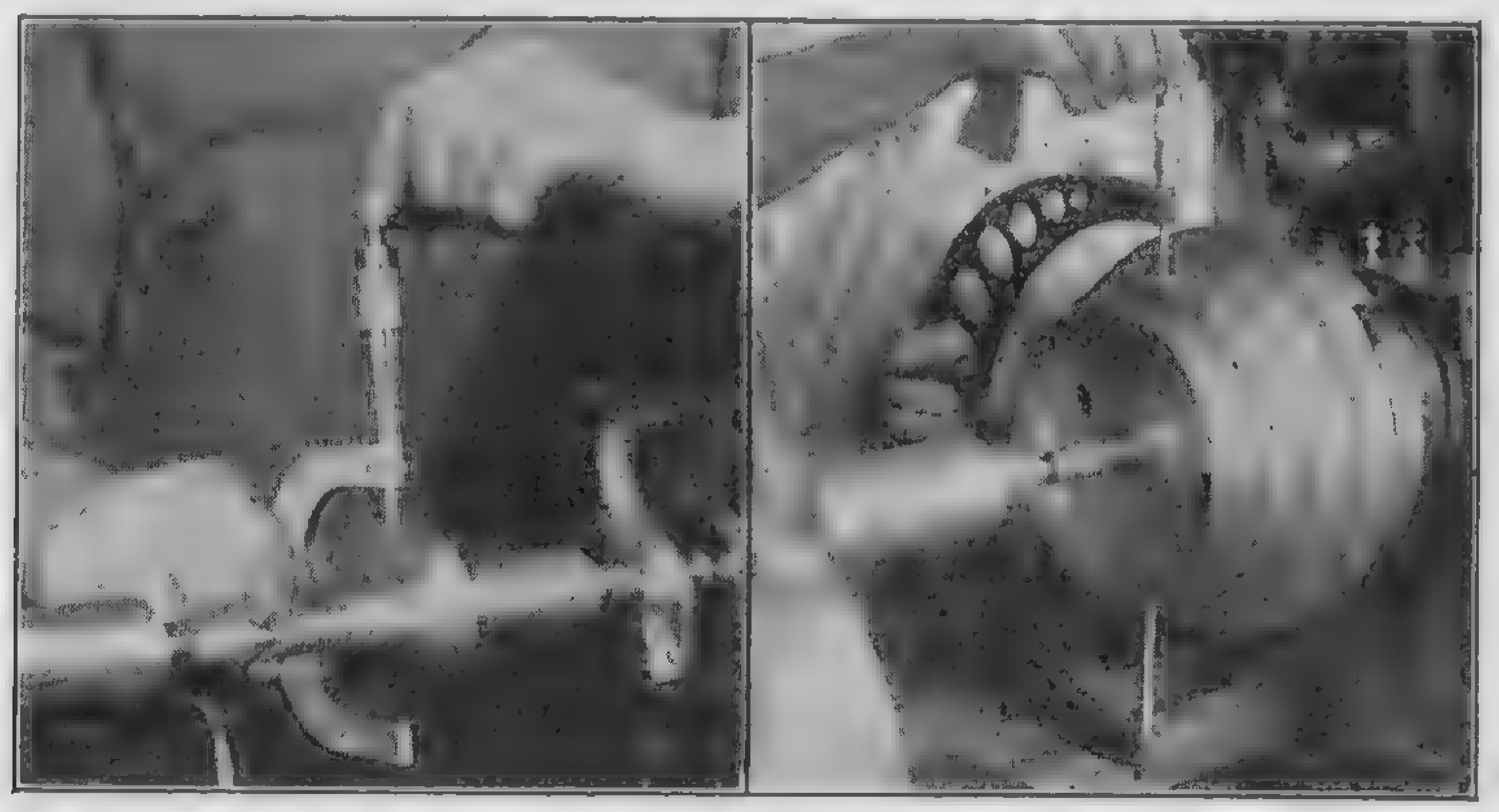


Fig. 29. Suggestions on Using a Micrometer Caliper
*Courtesy of Brown & Sharpe Mfg. Co., Providence, R.I.*

2. Adjust the micrometer with the ratchet stop until you develop the necessary feel on the thimble. In adjusting the micrometer with thimble, exert no pressure whatever. Merely let thumb slip lightly over thimble.
3. If possible, make the reading while the micrometer is on the work.
4. Open the micrometer before removing it from the work. This prevents wear on the ends of the anvil and the point of the spindle.
5. Never measure rotating work. Never measure while machine is in motion.





6. Never use an air hose to clean off your micrometer. Doing this forces dirt, grit, and oil into the delicate mechanism and throws it out of adjustment.
7. Have your micrometer checked for accuracy frequently. You can do this in the gage room of the plant in which you work.

### HOW TO TRANSFER A MEASUREMENT FROM INSIDE CALIPERS TO A MICROMETER

With a little care it is rather easy to transfer a measurement from the inside calipers to the micrometer, Fig. 30. After setting the calipers to the work being measured, follow carefully the procedure outlined here:

1. Hold the micrometer in the left hand, and the calipers in the right hand.
2. Turn the thimble with the thumb and forefinger until you feel the caliper legs lightly in contact with the measuring point of the micrometer.

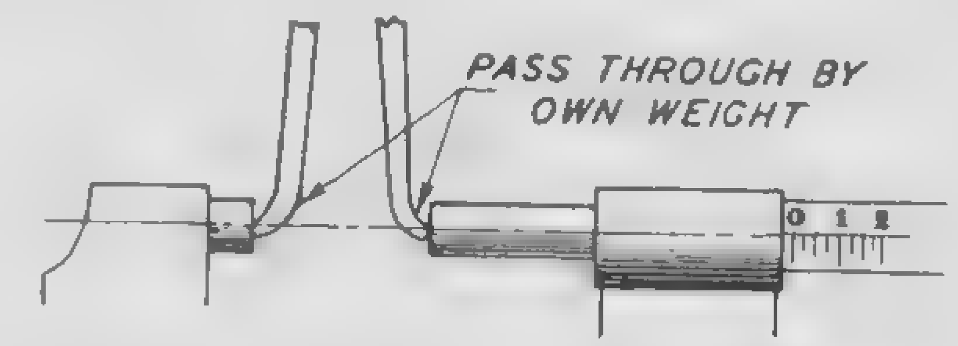



Fig. 30. Transfer of Measurement from Inside Calipers to Micrometer

3. Hold the tips of the caliper legs parallel to the axis of the micrometer spindle.
4. The micrometer is accurately set when the caliper will just pass between the anvil and the end of the spindle by its own weight.

## VERNIER CALIPERS

A common use of a Vernier is its application to a caliper square, termed a Vernier caliper. Fig. 31 shows a representative tool.

**HOW TO READ THE VERNIER.** The following text represents The L. S. Starrett Company's instructions for reading their Vernier caliper square, Fig. 31:

The scale of the tool is graduated in fortieths, or .025 of an inch, every fourth division, representing a tenth of an inch, being numbered. On the Vernier plate, shown on the movable arm and facing the scale on the square, is a space divided into twenty-five parts and numbered 0, 5, 10, 15, 20, 25. The twenty-five divisions on the Vernier occupy the same space as the twenty-four divisions on the scale.

The difference between the width of one of the twenty-five spaces on the Vernier and one of the twenty-four spaces on the scale is, therefore, $\frac{1}{25}$ of $\frac{1}{40}$, or $\frac{1}{1000}$ of an inch. If the Vernier is set so that the 0 line on the Vernier coincides with the 0 line on the scale, the next two lines will not coincide by $\frac{1}{1000}$ of an inch; the next lines will be two thousandths apart, and so on. Only the 0 and the 25 on the Vernier coincide with lines on the scale.

To read the tool, note how many inches—tenths or .100, and fortieths or .025 inches—the 0 mark on the Vernier is from the 0 mark on the scale; then note the number of divisions on the Vernier from 0 to a line which exactly coincides with a line on the scale.

In Fig. 32 the Vernier has been moved to the right one and four-tenths (1.400) and one-fortieth (.025) inches (1.425 inches), as shown on the scale, and

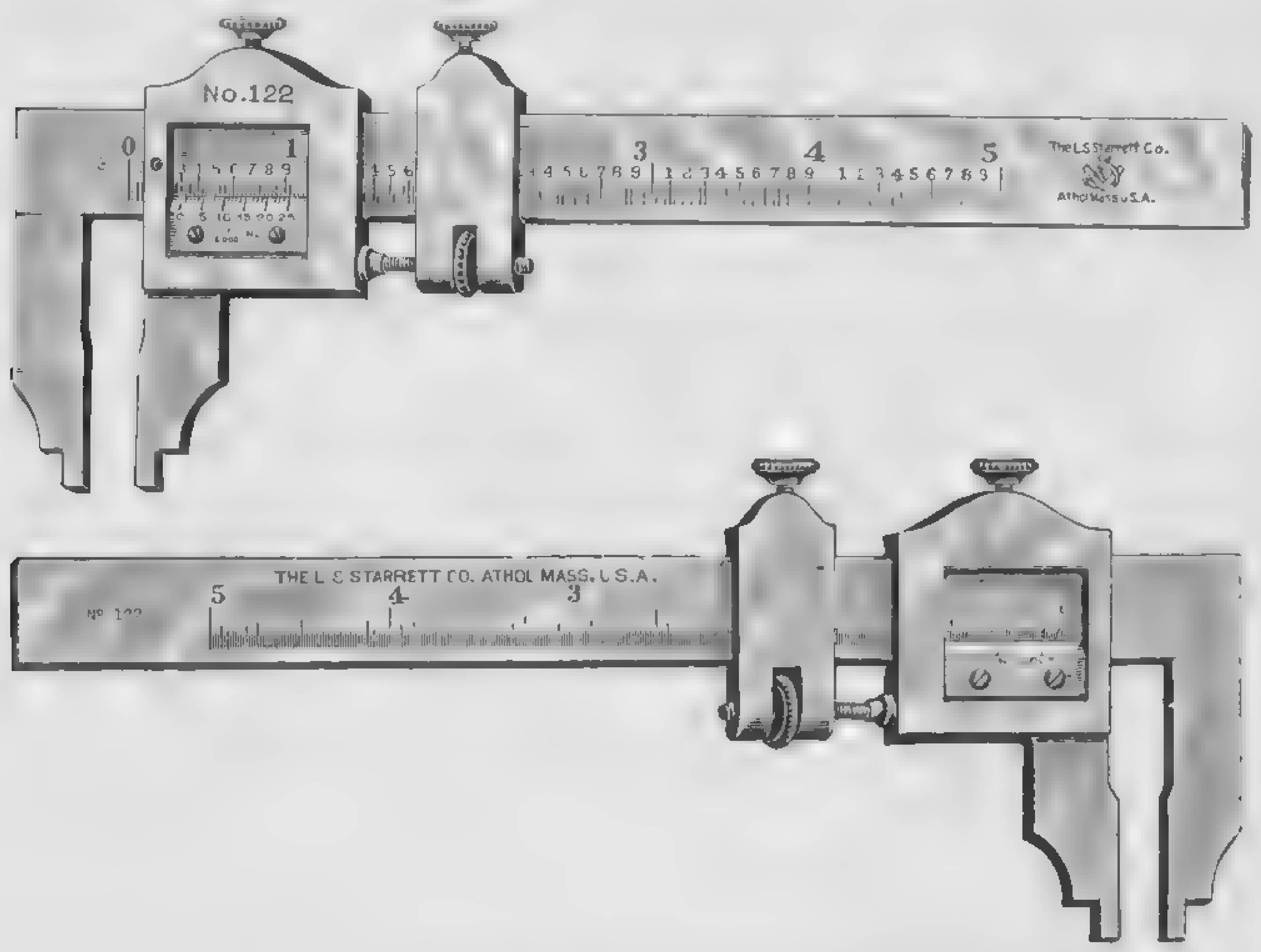



Fig. 31. Front and Back View of Vernier Caliper

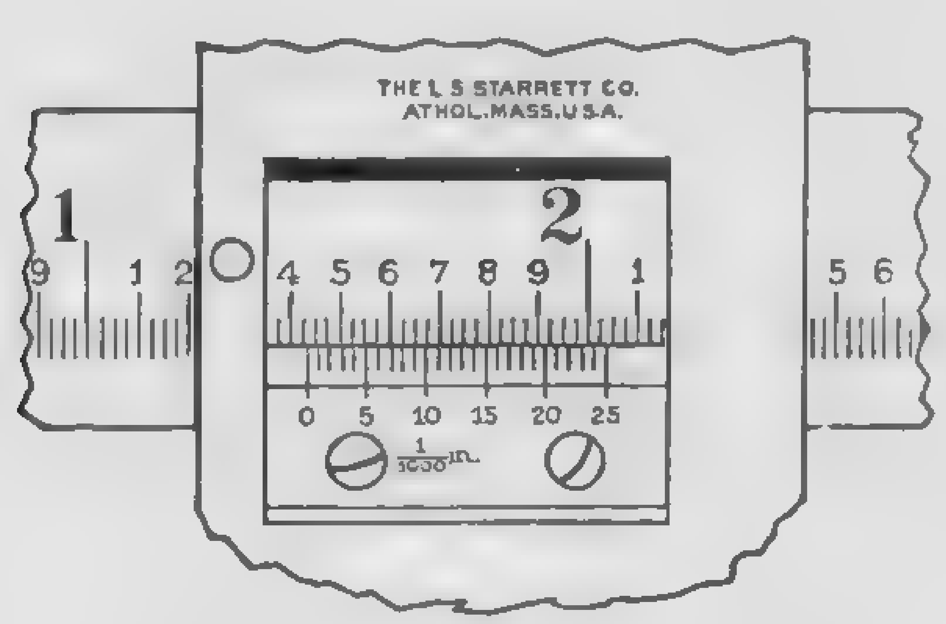



Fig. 32. Enlarged View of Vernier

the eleventh line on the Vernier coincides with a line on the scale. Eleven thousandths of an inch are therefore to be added to the reading on the scale, and the total reading is one and four hundred and thirty-six thousandths inches (1.436 inches), which is the distance the jaws of the tool have been opened.

In making inside measurements, the width of the jaws, as given in the list, is to be added to the apparent readings on the side having the Vernier to allow for the space occupied by the measuring points. No such allowance is necessary when using the back side, without Vernier, as the two lines marked "in" and "out" indicate inside and outside measurements.





## QUESTIONS

1. *How close may micrometers be adjusted to measure?*
2. *What is the number of threads per inch on the screw part of the sleeve or thimble?*
3. *Giving the thimble one exact turn increases the opening between anvil and spindle how much?*
4. *What is the purpose of the micrometer ratchet?*
5. *What is the purpose of the micrometer lock nut?*
6. *Explain how the accuracy of the micrometer may be destroyed by handling.*

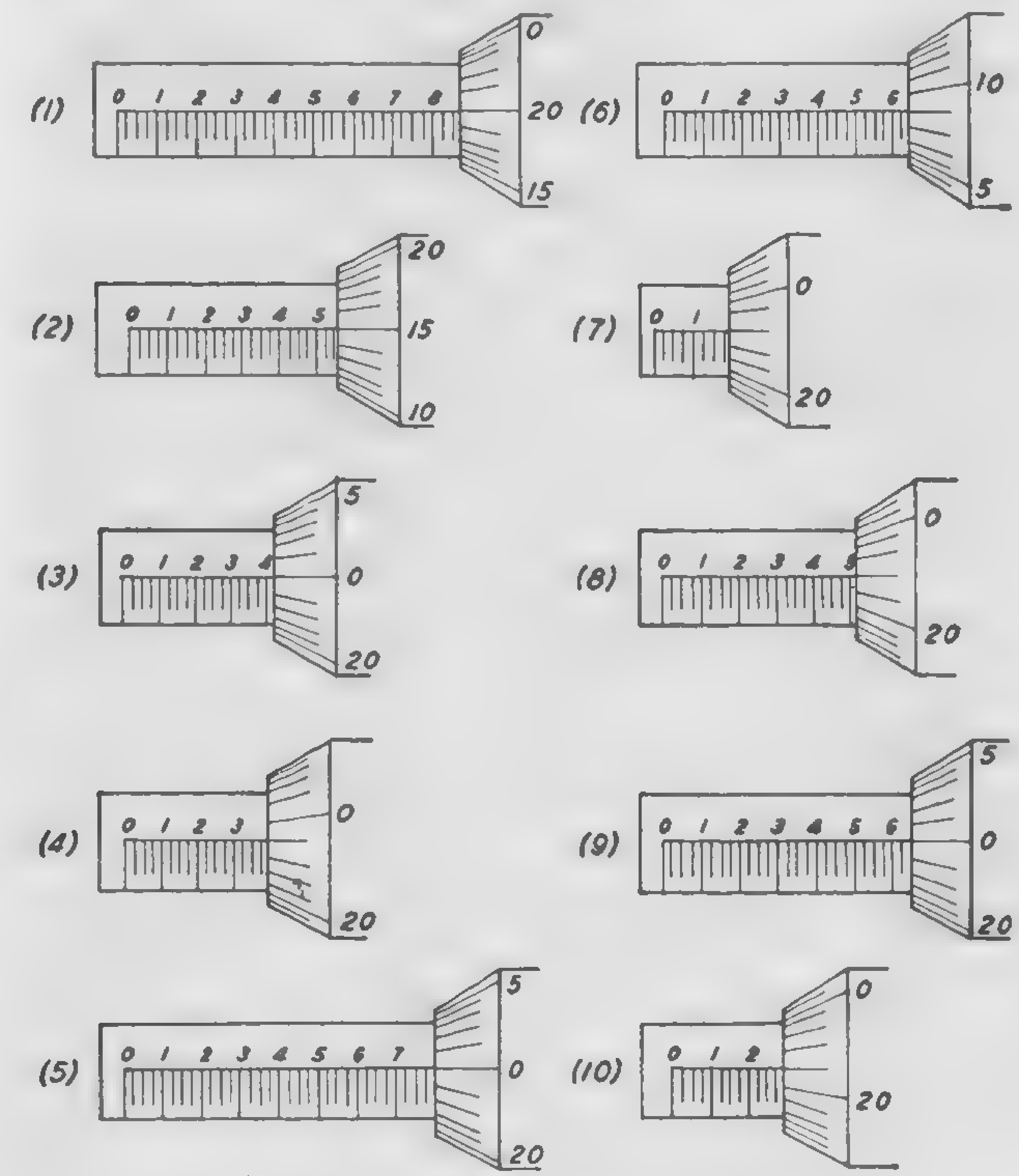
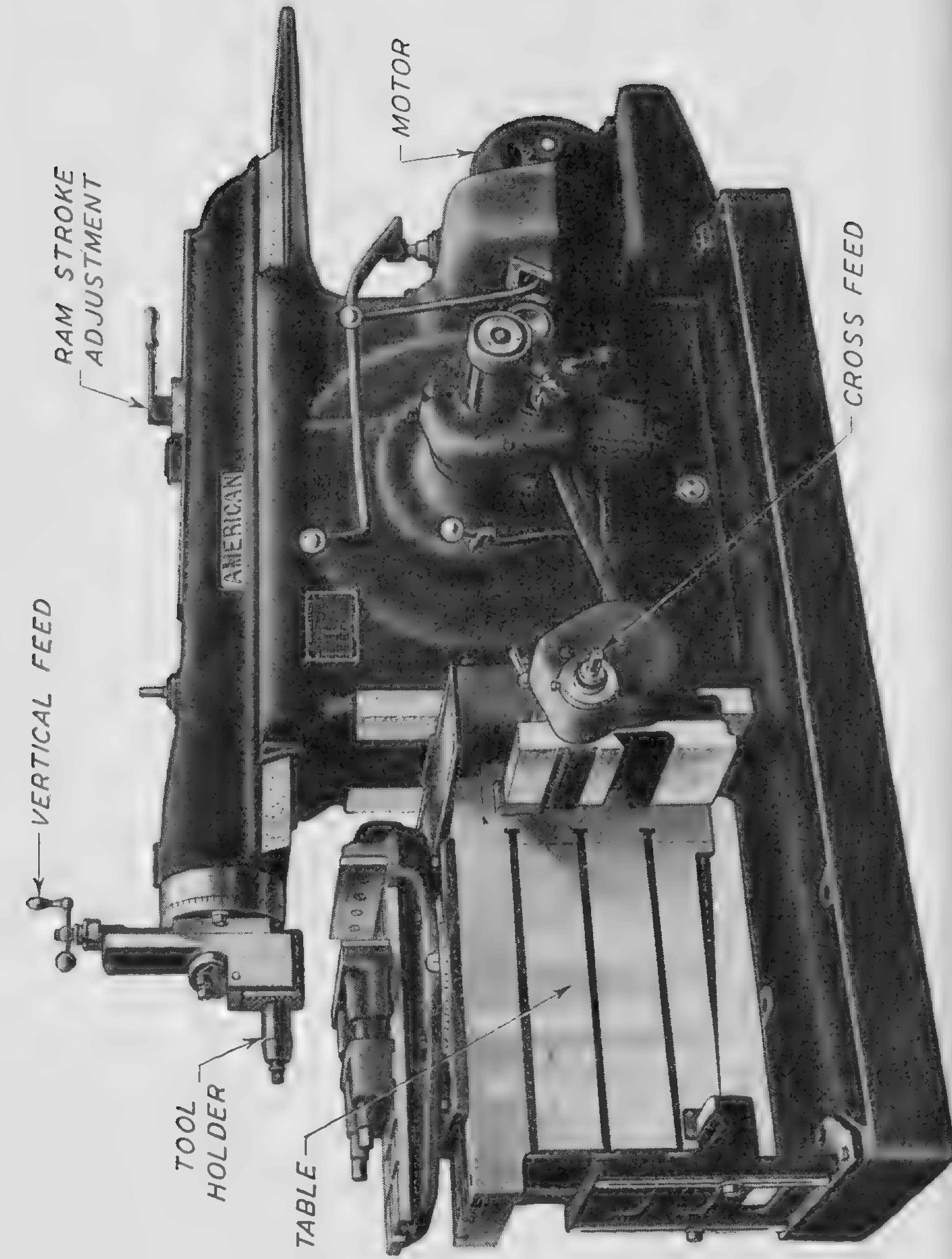



Fig. 33. Problems in Reading the Micrometer

7. *State the common shop name for micrometers.*
8. *What does the phrase "mike the job" mean?*
9. *When is the micrometer spoken of as being "set"?*
10. *What harm is caused by dust or dirt on the anvil or spindle?*
11. *Is it considered good practice to try the micrometer on a job while the job is in motion?*
12. *What good or bad effect does oil have on the accuracy of the micrometer?*
13. *Give the readings of the micrometer calipers shown in the ten positions in Fig. 33.*




MODERN HEAVY-DUTY SHAPER WITH STANDARD TABLE

# Drilling Machines

One of the most efficient machine tools is the drill press which is used to cut round holes through metal. It employs a variety of tools of which the twist drill is the most common one used in the many operations of the drill press.

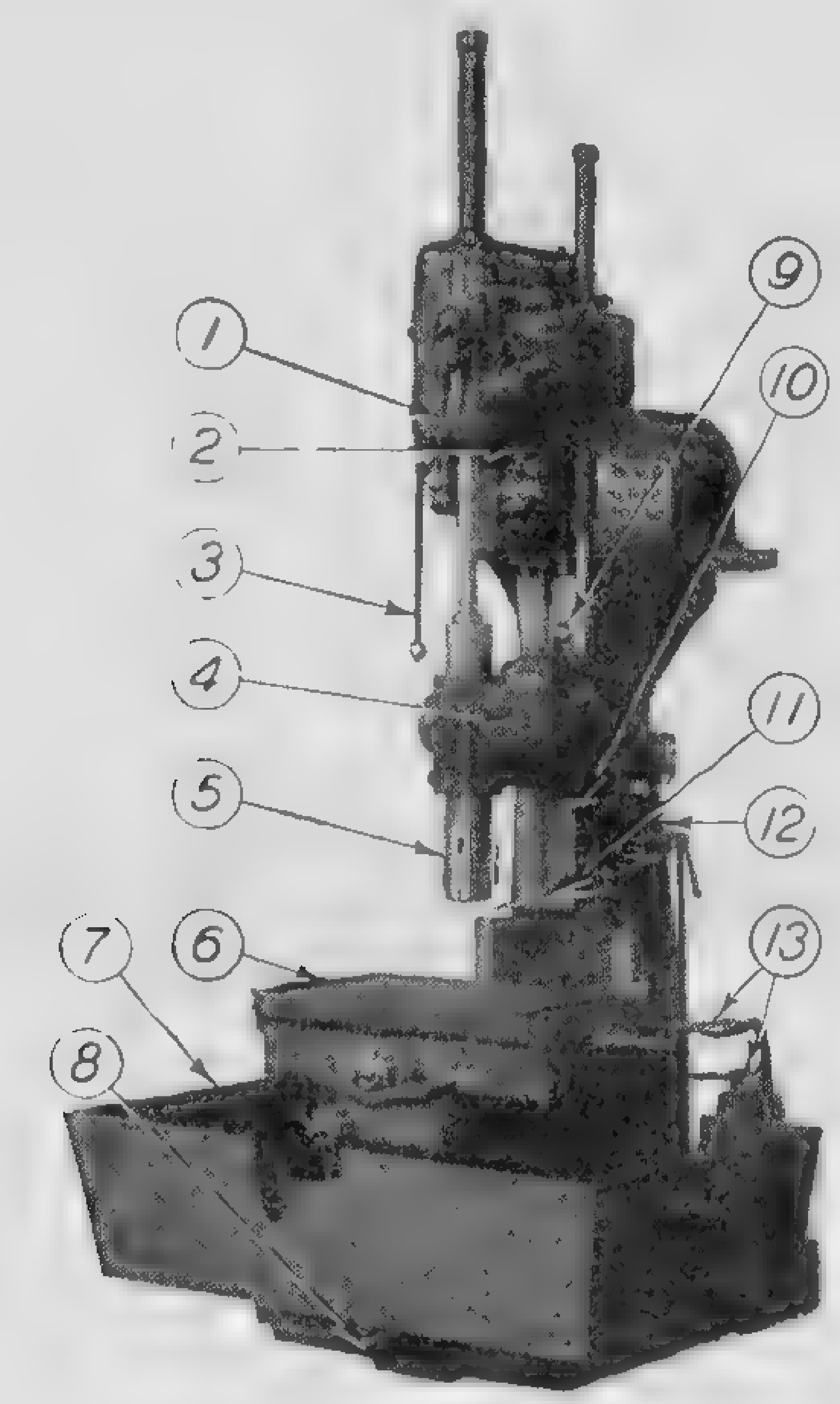


Fig. 1. Upright Drill Press

1) Speed Change Lever
2) Feed Change Lever
3) Reverse Switch Lever
4) Sliding Head
5) Spindle
6) Table
7) Chip Pan
8) Base
9) Quick Return Lever
10) Feed Hand Wheel
11) Cutting Lubricant Nozzle
12) Box Column
13) Cutting Lubricant System

*Courtesy of Cincinnati Bickford Tool Co.; Cincinnati, Ohio*

**UPRIGHT DRILL PRESS.** Drill presses are built in a variety of types, but the ordinary upright drill is to be found in nearly every machine shop. Such a machine is illustrated in Fig. 1. Work may be

clamped in any position or location on the table and centered under the drill. This type of machine may have as many as 12 spindle speeds and 9 feeds which are adequate for the usual run of drilling work.

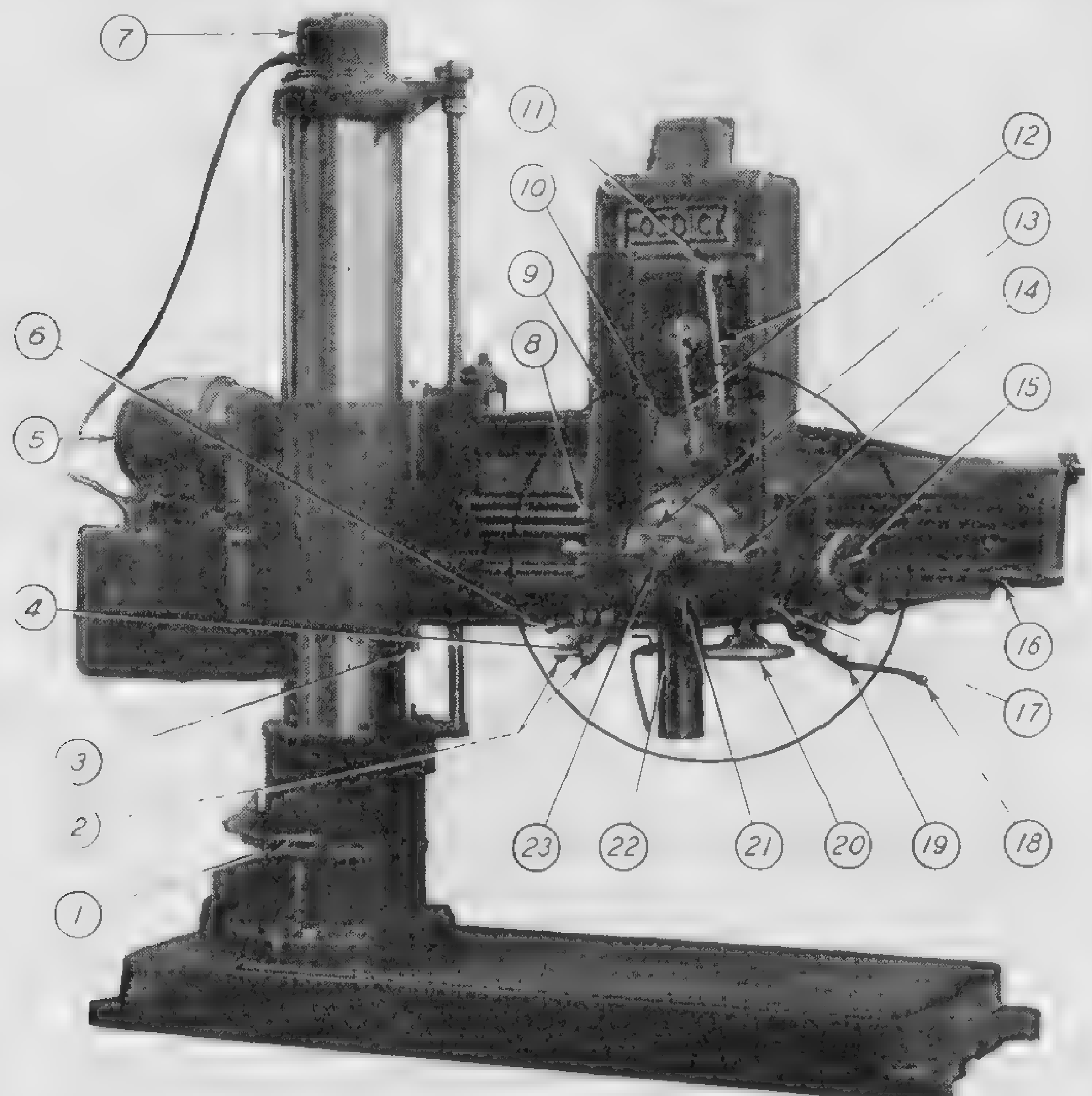



Fig. 2. Radial Drill Press

① Column Clamp Hand Lever
② Speed Change Levers
③ Arm Traverse Safety Switch
④ Hydraulic Column Clamp Lever
⑤ Constant Speed Motor
⑥ Head Clamp Lever
⑦ Revolving Electric Unit
⑧ Speed Change Lever
⑨ Radial Drill Control Levers All Within This Circle
⑩ Drill Speed Dial
⑪ Coarse Feed Interlock Inside
⑫ Feed Change Levers for Eighteen Speeds
⑬ Depth Dial Clamp
⑭ Feed Clutch Lever
⑮ Head Traverse Hand Wheel
⑯ Head Traverse Screw
⑰ Lever for Clamping, Unclamping, Raising and Lowering Arm Hydraulically
⑱ Start, Stop, and Reverse Lever
⑲ Variable Rapid Traverse Lever Hydraulically Controlled
⑳ Feed Hand Wheel
㉑ Feed Trip Pin
㉒ Spindle with Safety Stop and Catch, Also Feed Interlock
㉓ Adjusting Nut for Feed Clutch

*Courtesy of Fosdick Machine Tool Co., Cincinnati, Ohio*

The size of such a machine is indicated by the diameter of the largest piece that can be drilled on the table.

Almost anyone can drill a hole, but to drill the proper size hole in an exact location requires considerable skill. This necessitates accurate layout and a correctly ground and aligned drill. Intelligent





operation of the drill press includes proper setting-up of the work, selection of the correct speed and feed, the use of the right coolant, recognition of satisfactory cutting results from the drill, and an adequate working knowledge of the machine itself. Drill press work is the more important because making the holes is usually the last opera-

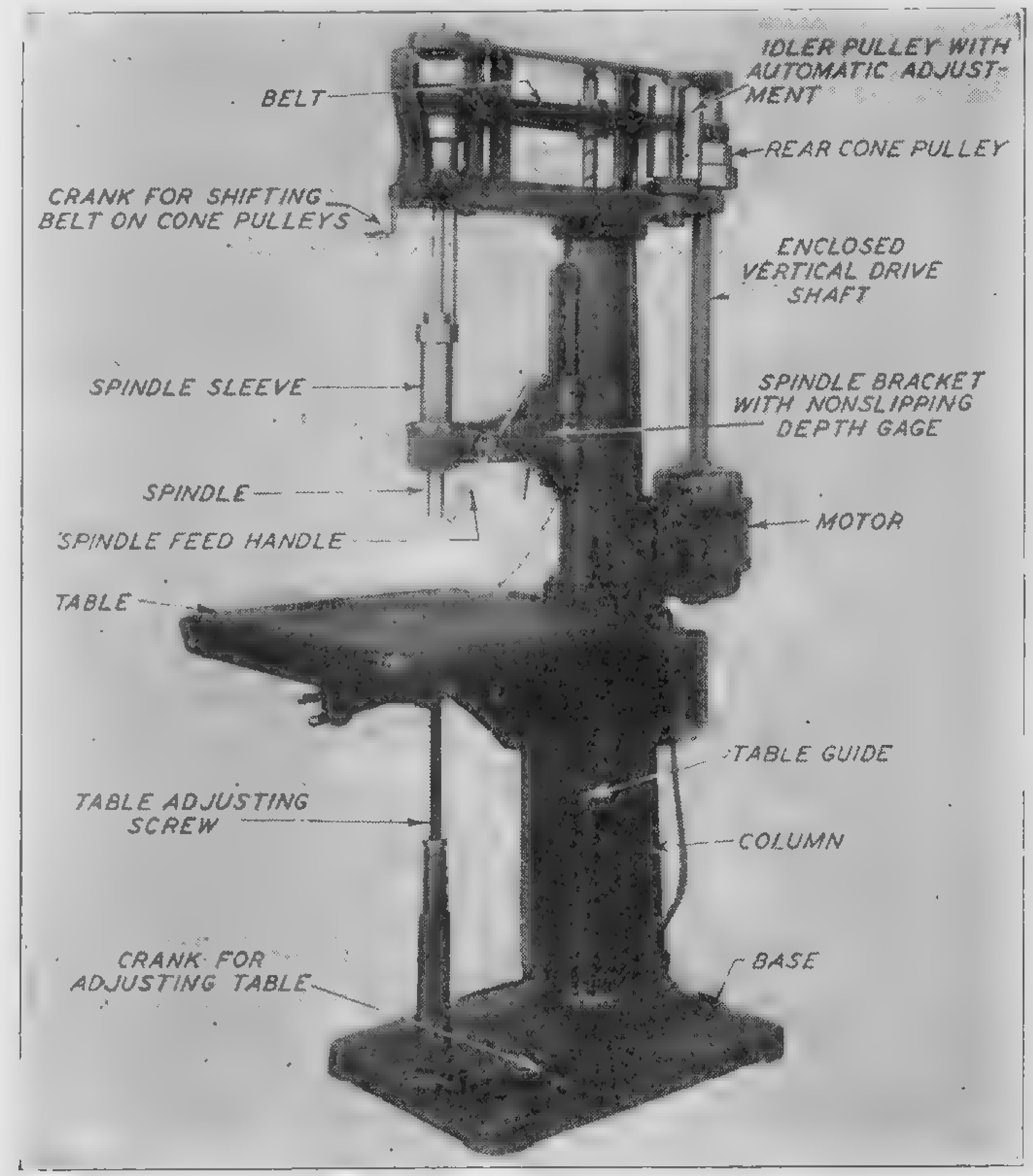



Fig. 3. Sensitive Drill Press

*Courtesy of Providence Engineering Works, Inc., Providence, R. I.*

tion before assembly. If the holes are "messed up," perhaps hundreds of dollars worth of previous machine work is wasted through poor workmanship. The beginner must, of necessity, be guided by various formulae and charts, but the experienced operator will judge the efficiency of his drilling by the appearance of the chip and the action of the machine. Industry today demands all the speed and feed that the drill and drill press can efficiently accommodate.

**RADIAL DRILL PRESS.** For heavier production work, the radial type is necessary. This machine, an example of which is shown in Fig. 2, can handle larger work and has a wider range of adjustments than the upright drill press. Its chief distinction is the employment of an arm or radial which carries the head and allows the drill to be moved over a large area and also to be swung at an angle for angular drilling. The length of the arm, in this case, gives the size of the machine.

Pits in the floor beside the radial drill press are sometimes provided for drilling large work. These are kept covered when not in use.

**SENSITIVE DRILL PRESS.** The sensitive drilling machine, Fig. 3, is designed for use with the smaller sizes of drills on work under conditions which make it necessary to "feel" what the cutting lips are doing. There are no trains of gearing present in the spindle-driving mechanism, and the tool is fed into the work by the simplest and most direct device—a lever, a pinion and shaft, and a rack which engages the pinion. This is the simplest form of effective drilling machine. It is started and stopped by operating the motor switch. The end of the spindle is bored to a standard Morse taper. Taper shank drills may be fitted to the spindle, or a drill chuck may be used for straight shank drills.

## HOW TO OPERATE A DRILL PRESS

**HORIZONTAL AND VERTICAL ADJUSTMENTS.** The principal parts of an upright drill press include the base, column, table, head, spindle, back gearing, and driving mechanism. Adjustment for height may be made by raising or lowering the table and head. In some machines, the head is stationary. The table is often free to swing in an arc about the column and is also pivoted so that it may be turned. With these two adjustments, work mounted upon the table may be brought into position under the drill.

**SPINDLE.** The spindle is rotated within a sleeve which is free to move up and down. Spindle speeds are regulated either by cone pulleys or a gear box. The feeding of the spindle is accomplished in the following three ways:

1. By moving the handle connected to a pinion which engages the rack on the back of the spindle sleeve.





2. By engaging the gears which permit the spindle to be moved by turning the hand wheel.

3. By engaging these same gears and throwing in the power feed.

**BACK GEARING.** Back gearing is a system of compound gearing whereby greater power is supplied to the spindle. This increase in power is accompanied by slower speeds which are a result and not a purpose of back gears.

Changing to the back gear is done by pulling out a pin on the face gear (located at the top of the machine) and changing a lever which meshes the driving gears. This operation is similar to the indirect driving system of a lathe. On some uprights, changing to the back gear involves merely shifting a lever conveniently located at the side of the machine. Selection of feeds requires shifting of a belt (where the feed is belt driven) or changing gears (when a feed gear box is used). Feed selection tables are located at the front of the machine for instant selection.

### QUESTIONS

1. *What are the principal parts of the upright drill press?*
2. *Why are several spindle speeds provided in the drill press?*
3. *What is the difference between "speed" and "feed" and how are these regulations accomplished?*
4. *What is meant by setting-up work?*
5. *How does the drill press operator determine how fast to run the machine?*
6. *What is a radial drill press?*
7. *Mention several differences between the radial and the upright drill press.*
8. *How is the size of a radial drill press determined?*
9. *What determines the size of an upright drill press?*
10. *What is a sensitive drill press?*
11. *Is a sensitive drill press a high- or low-speed machine?*
12. *What is meant by back gearing?*
13. *Does the sensitive type drill press have back gears?*
14. *In the radial type drill press, is the work centered under the drill?*
15. *How is work centered on the upright machine?*
16. *How is a drill held in the spindle? (Two methods)*
17. *What is meant by the cutting speed of a metal?*
18. *What general rule may be followed with respect to size and speed of a drill?*
19. *When is a cutting oil necessary?*
20. *Name several metals which do not require cutting oils.*
21. *Cutting speeds depend on what conditions?*
22. *For what is an automatic stop used?*
23. *How can the depth of the drilled hole be measured by the machine?*
24. *Is the drill press an efficient machine tool?*
25. *Is drill press work considered important in industry?*

**STEPS IN PREPARING WORK.** The following procedure is used in properly preparing work for the drill press:

1. Lay out the work
2. Clamp work to table
3. Insert proper size drill
4. Select most suitable speed and feed
5. Drill job

## STEP 1—LAYOUT OF WORK

**LAYING OUT CIRCLES.** Laying out must be accurate if the consequent drilling is to be satisfactory. When laying out circles, the first item to check carefully is the diameter of the circle. If a number of equally spaced holes is to be drilled on the circle, the divider setting must be precise. Tables in any reference book will give the constants for any number of holes on a one-inch circle, and these constants can be multiplied by the diameter of the required circle to give the divider settings.

**Example.** Suppose 10 holes are to be drilled on a 12-inch circle. Reference to the table shows that the constant for 10 holes on a 1-inch circle is .309. Multiply .309 by 12 inches and the result is 3.708 inches. This is the divider setting.

Although the trial and success method will produce results, considerable time will be saved by setting the dividers by the method just explained. Lightly punch a mark from which to begin stepping off, keep the divider points exactly on the circle at each pivot, and do not be satisfied until the divider point rests perfectly in the indentation after the last pivot. Be sure to count the spaces, for error often results in this spacing process.

At times, it is necessary to get a circle on a piece which has a hole at the center. Then, it is necessary to bridge the hole with a piece of wood to which a small piece of tin is tacked, affording a stable center for the dividers, as shown in Fig. 4. The center may be located with hermaphrodite calipers from the surface with which the holes must be concentric.

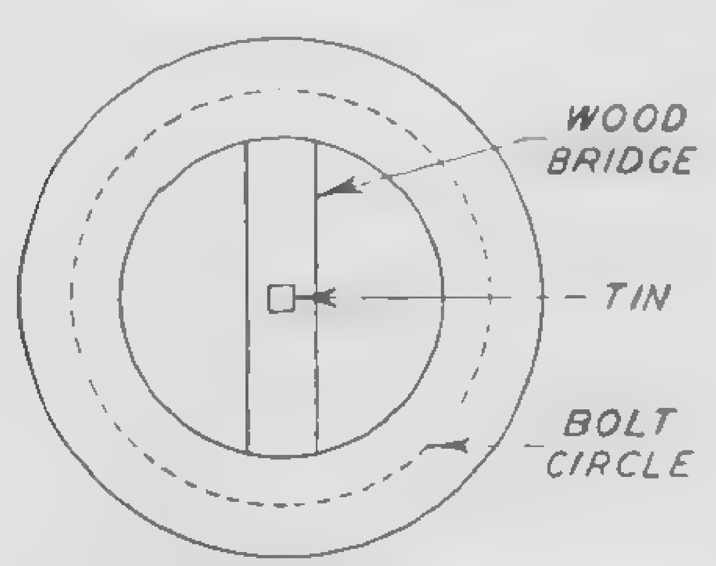



Fig. 4. Bridging a Hole in Work to Lay Out the Bolt Circle

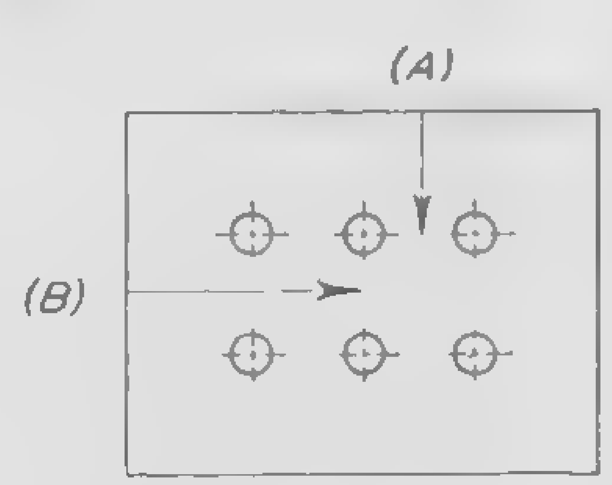



Fig. 5. Die Layout





**WORK FROM CENTER LINES.** It is always good practice to work from center lines. Since two intersecting lines make a point, good results are obtained when lines are properly placed. In the case of a layout on flat machined work, the holes should be laid out from two adjacent edges, rather than from all four.

In Fig. 5, all holes are located from both edges (*A*) and (*B*).

After the center marks have all been located, the dividers should be set to the radius of the drill to be used and circles scribed about the centers. These circles are then lightly punched with a prick punch to identify the bounds of the circle after the circle itself has disappeared. Accurate drilling necessitates such procedure.

**Caution.** Metals upon which layouts are to be made should always be treated with some layout coating. Chalk, whiting mixed with gasoline, or keel, are suggestions for rough surfaces. Divider points are very delicate and should be kept sharp. To try to scratch metal with them every time a layout is made soon ruins the points. A layout coating applied to the metal will make it unnecessary to dig the points of the dividers into the metal.

### QUESTIONS

1. *Why is a layout necessary?*
2. *How should the metal be prepared for laying out?*
3. *What hand tools are necessary for laying out?*
4. *Describe the method of stepping off spaces on a circle*
5. *Name several laying out fluids and applications.*
6. *Why is a light punch mark made for the dividers?*
7. *Is it necessary to use center lines in layout work?*
8. *Why is the layout prick-punched?*
9. *What is a "bridge"?*
10. *What is a bolt circle?*
11. *Why is it essential that an accurate layout be made?*

## STEP 2—ACCESSORIES FOR CLAMPING THE WORK

**PARALLELS.** A variety of clamping devices expedites the process of fastening the work for drilling. Every machine must be equipped with sufficient accessories to eliminate time waste in setting-up. Because every drill press table is subject to damage, it is a good idea to mount the work on parallels, Fig. 6, whenever possible. The parallels

elevate the work above the table and enable the operator to observe better the progress of the drill. The parallels should be located in such

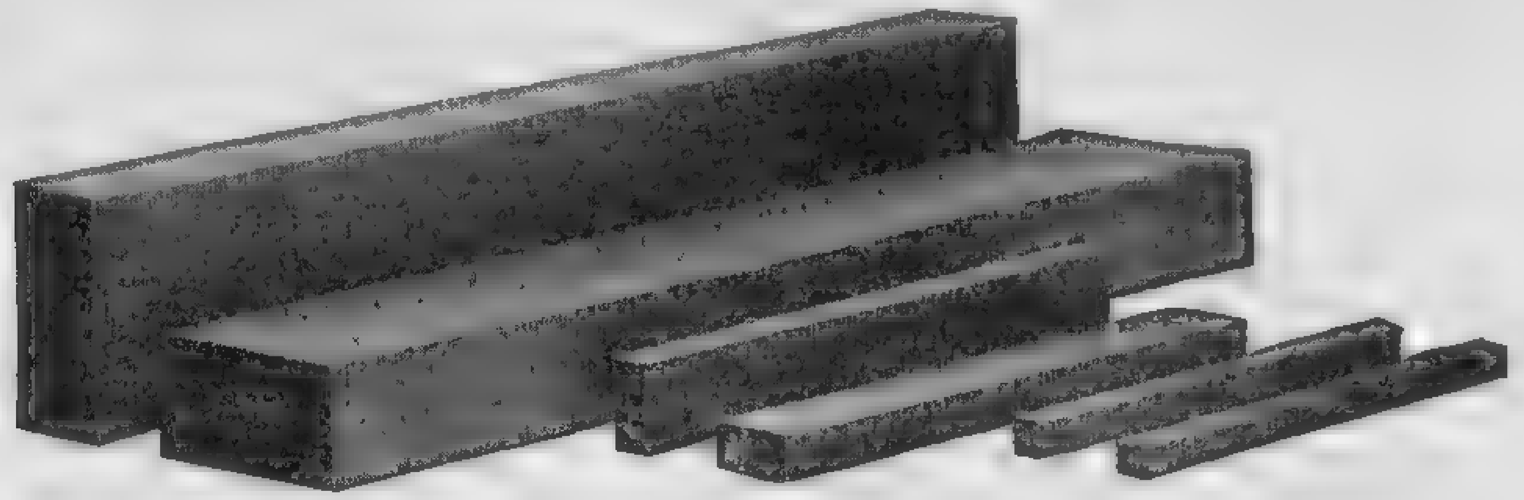


Fig. 6. Hardened and Ground Steel Parallels
*Courtesy of Taft-Peirce Mfg. Co., Woonsocket, R. I.*

a manner that the drill will not damage them in passing through the metal. Factory made parallels are hardened and ground and will resist the drill, but much drilling is done on work supported upon cast iron or machine-steel parallels, and these suffer much abuse if not properly located.

**VISE.** A vise, similar to the one shown in Fig. 7, is often useful for supporting and holding work to be drilled. A piece of wood or flat piece of iron should be placed under the work to protect the base of the vise when the drill breaks through. The vise should be clamped to the table when accurate drilling is attempted. To seat correctly work which is held in a vise, use parallels under the work. After the vise has been tightened, tap the work with a hammer. Do not try to tighten the jaws after seating, as the movable jaw will force the piece upward and out of level. If the parallels are loose, the work is not down on them and further tapping with a hammer is necessary.

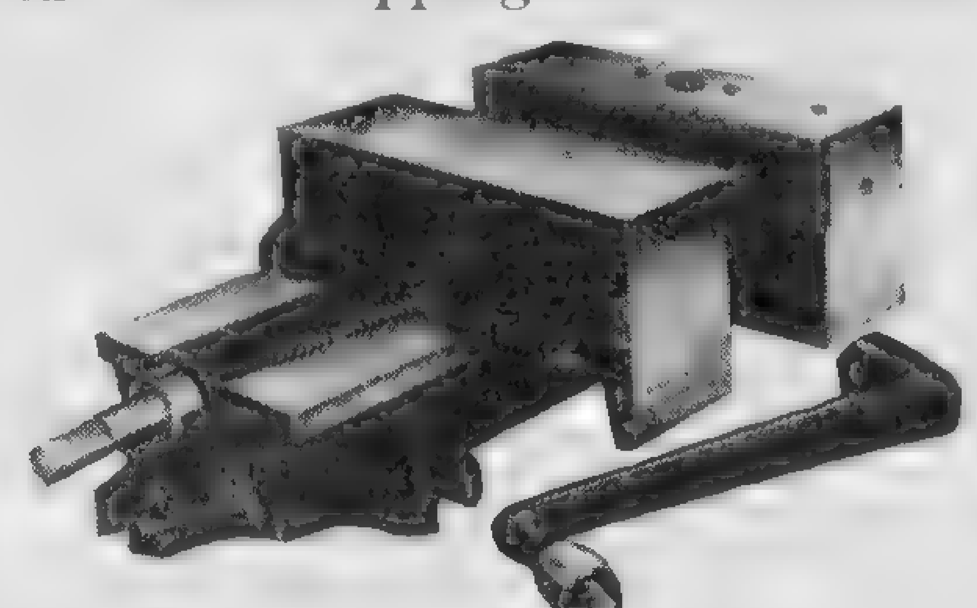


Fig. 7. Drill Press Vise
*Courtesy of The Graham Mfg. Co., Inc., East Greenwich, R. I.*

**V-BLOCKS.** V-Blocks in assorted sizes are necessary for supporting round stock. Some are provided with clamps, as shown in Fig. 8, while the larger style must necessarily be clamped with the work.





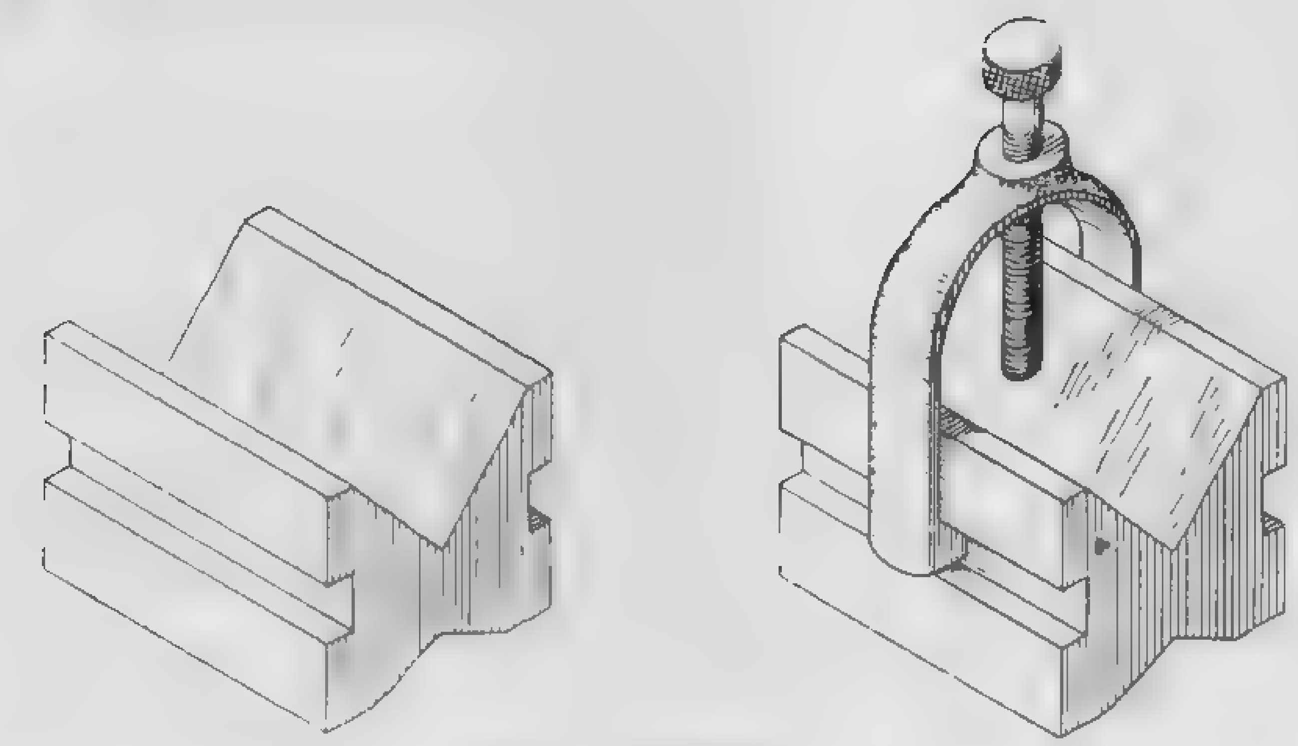


Fig. 8. V-Blocks

**ANGLE PLATES.** Another supporting device often used is the angle plate shown in Fig. 9. It is usually made of cast iron and is planed on two sides to an angle of exactly 90°. Holes and slots are provided in the plate for clamping it to the table and to secure the work. Angle plates are convenient when it is necessary to drill a hole parallel to another surface.

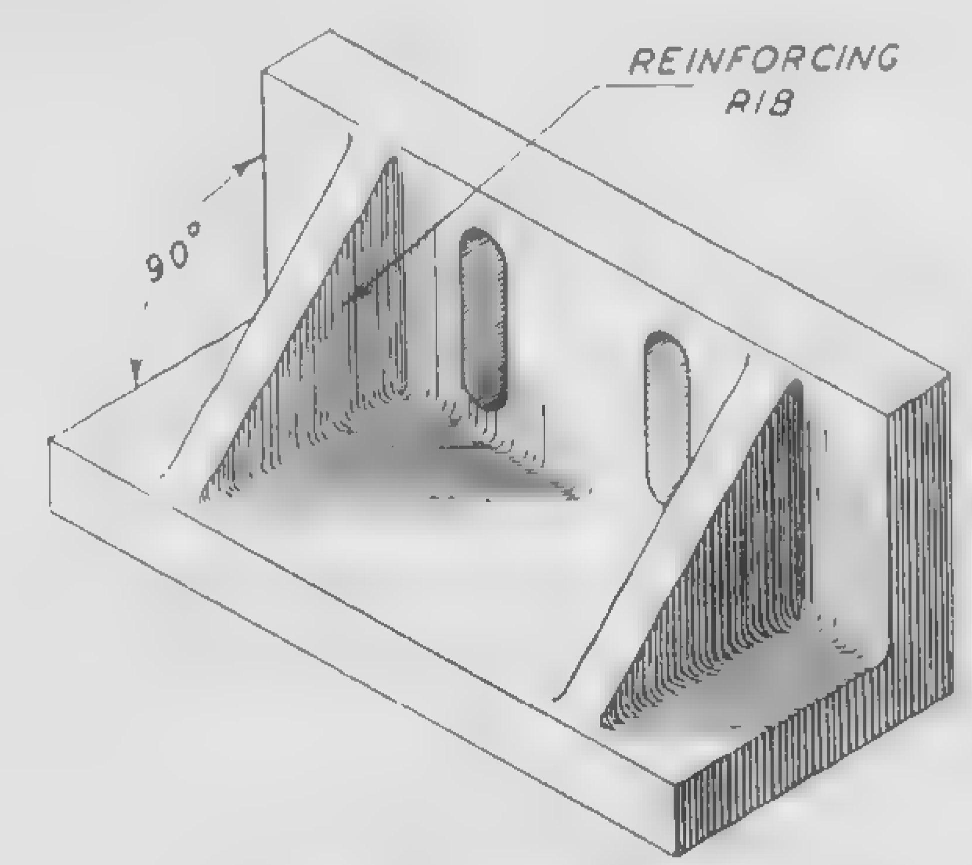



Fig. 9. Angle Plate

**T-BOLTS.** T-bolts placed in the T-slots of the drill press table are commonly used for fastening the work and the support to the table. Examples of these are shown in Fig. 10. Although the solid bolt is the sturdiest, the other two types have found favor, due to the convenience of inserting any length of stud. A few heads are sufficient for a number of different lengths of studs. The beveled type can be placed in the T-slot at any position. Turning it, locks it in place. One caution must be observed, however, in using the T-head. If the stud is screwed too far into the head, the head will be forced upward against the top of the table slot and may break out the supporting ribs.

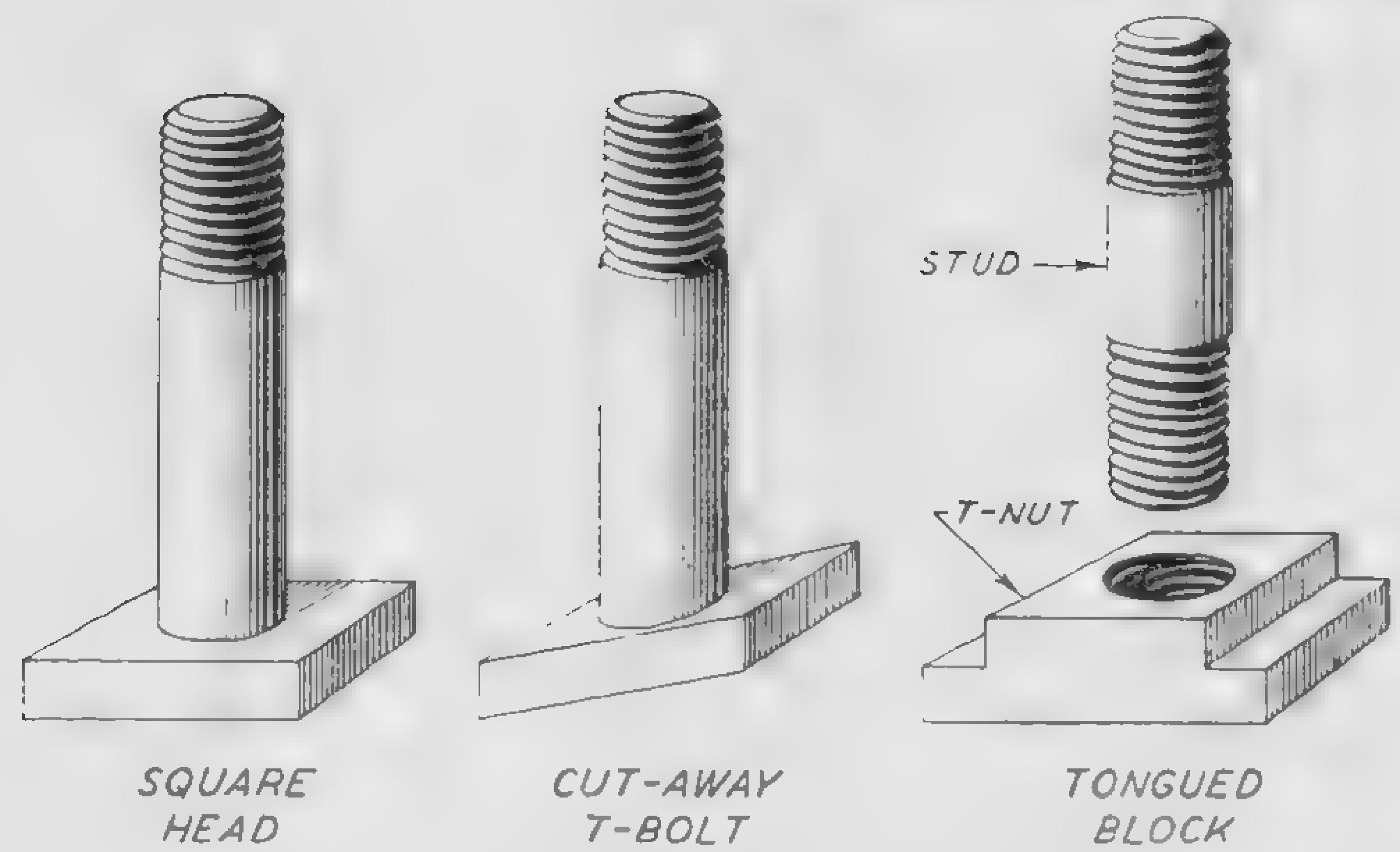



Fig. 10. Common Types of T-Bolts

**CLAMPS OR STRAPS.** Clamping work to the drill press table is made easier if a good assortment of clamps or straps is available. For many setups, the **U**-strap is more convenient as it allows adjustment without removing the nut. In cases where the clamp must bridge the work, a **U**-strap does not interfere with the drill and affords a

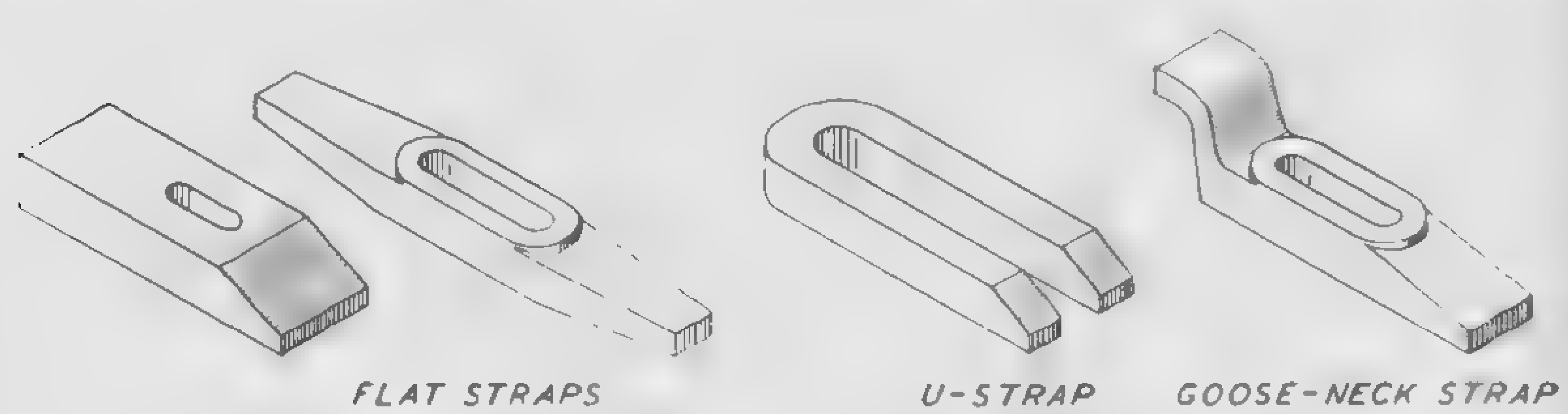



Fig. 11. Common Types of Straps or Clamps

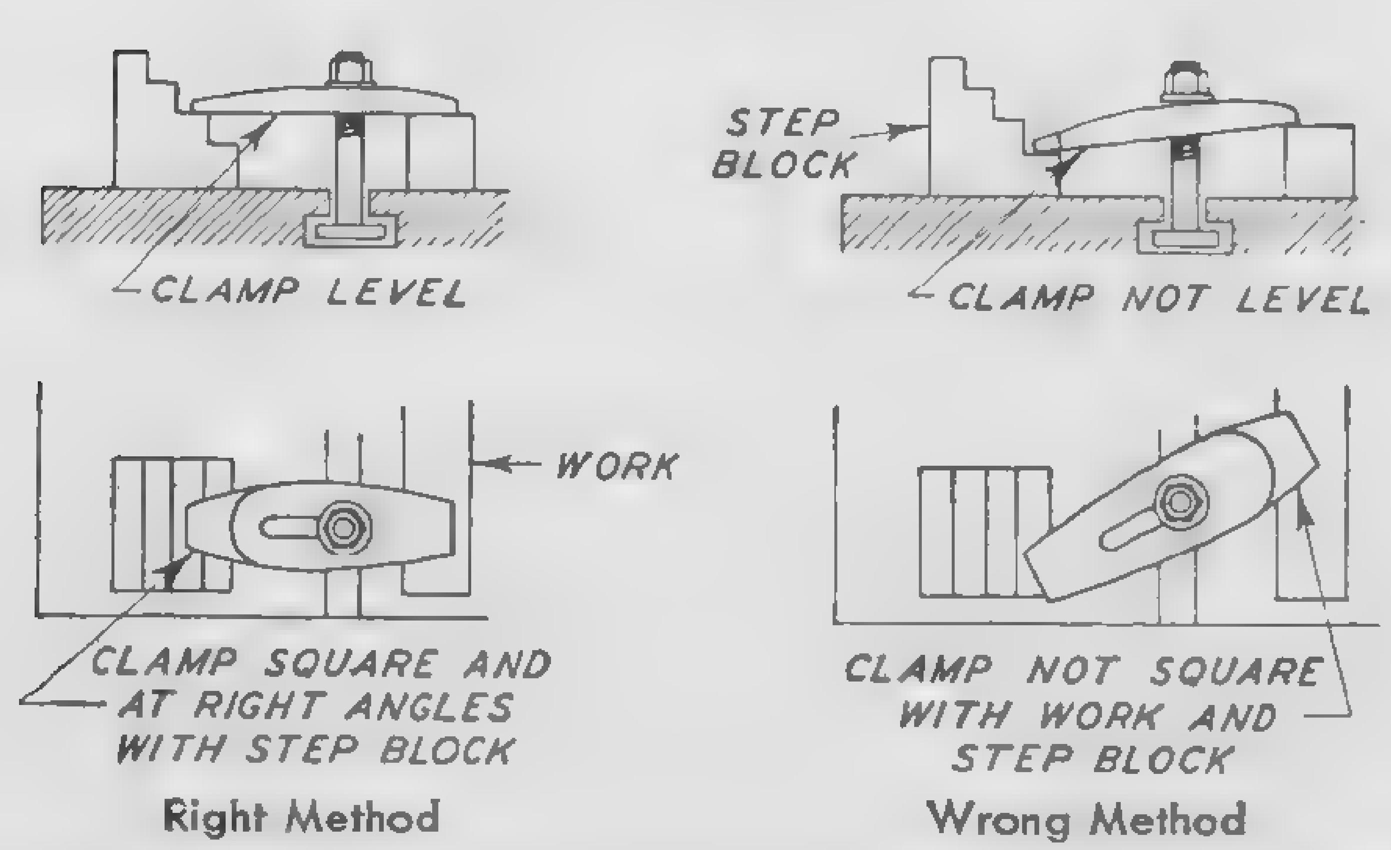



Fig. 12. Clamping a Job to the Work Table with the Use of Step Blocks





better view of the action of the drill. These clamps should be made from a good grade of steel to prevent bending under the pressure of the nut. The more common types of clamps are illustrated in Fig. 11.

**STEP BLOCKS.** To support the end of the clamp opposite the work, step blocks are used. These are of machine steel and are usually made in pairs. Since the clamps should be level when fastened in place, the step blocks at the end of the clamps should be of equal heights. Fig. 12 shows the right and wrong methods of securing clamps.

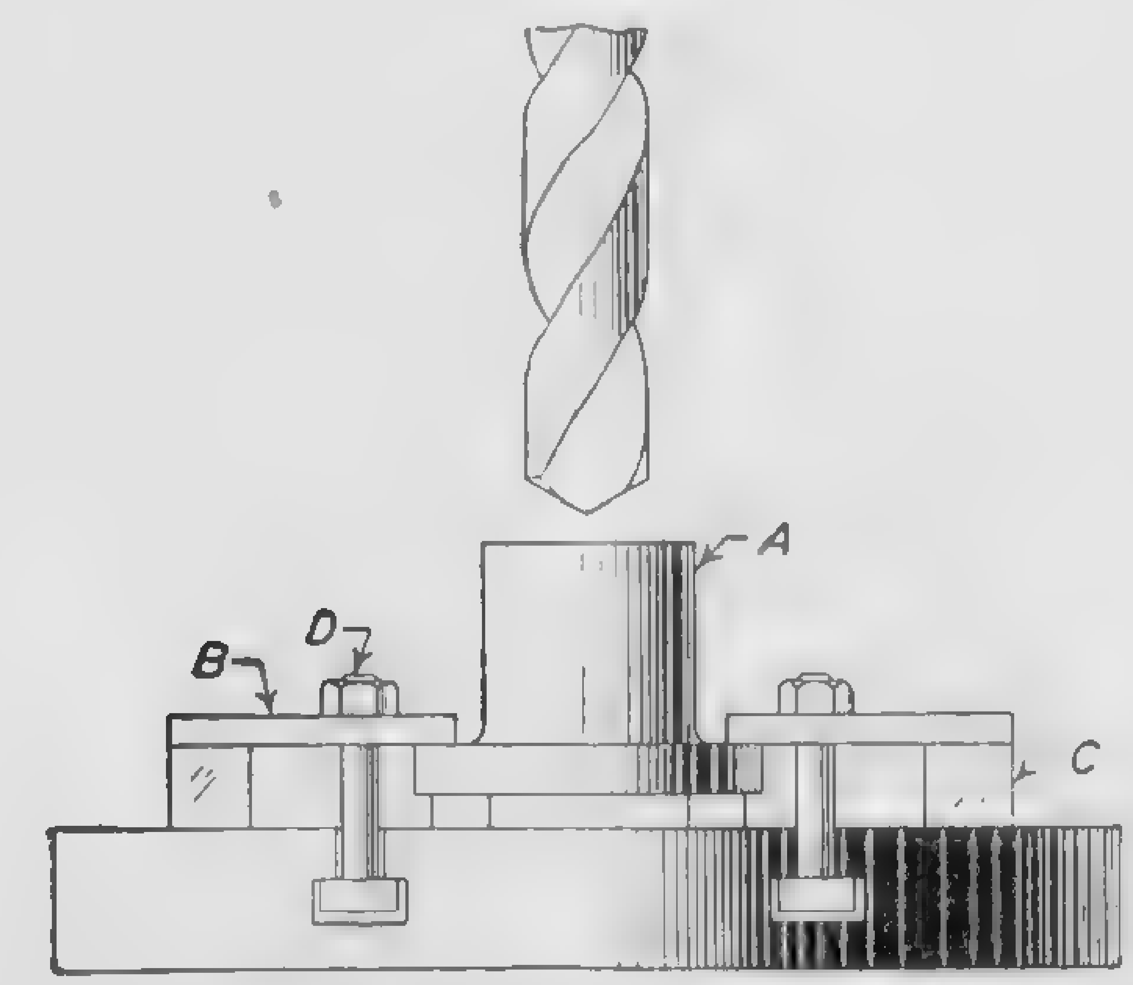



Fig. 13. Work Clamped to Table by Straps for Accurate Hole Drilling
*A*—work; *B*—clamp or strap; *C*—block; and *D*—nut and bolt.

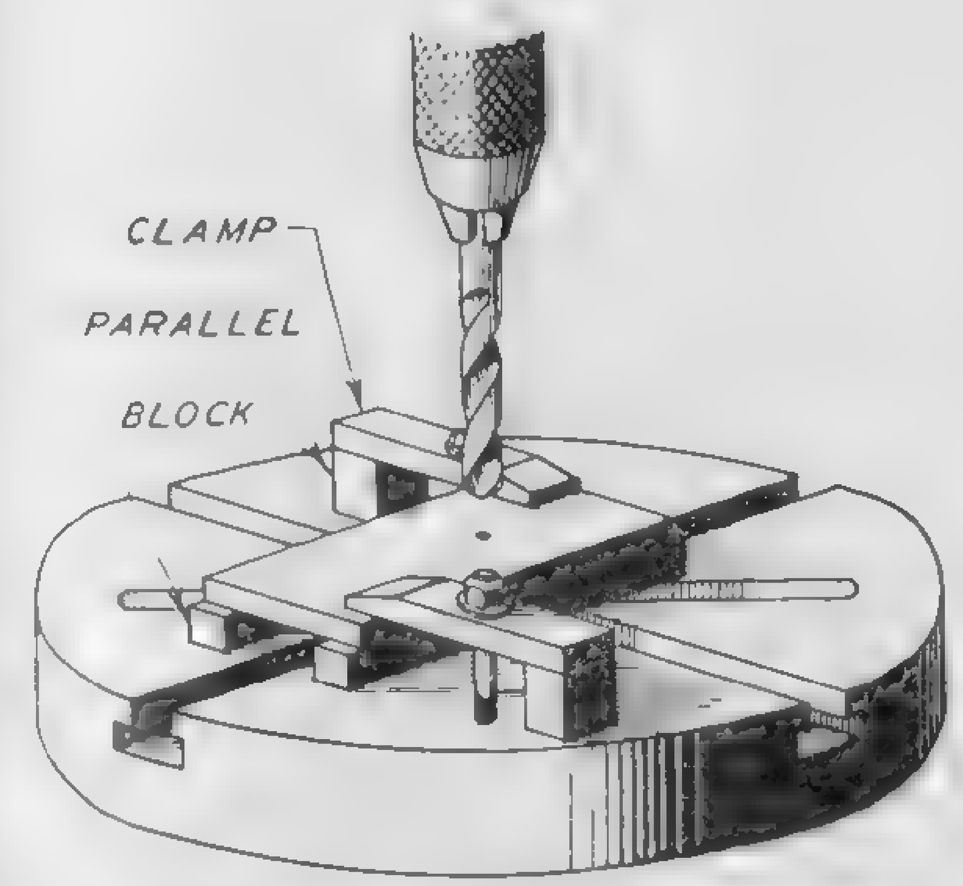



Fig. 14. Work Mounted and Clamped on Parallels

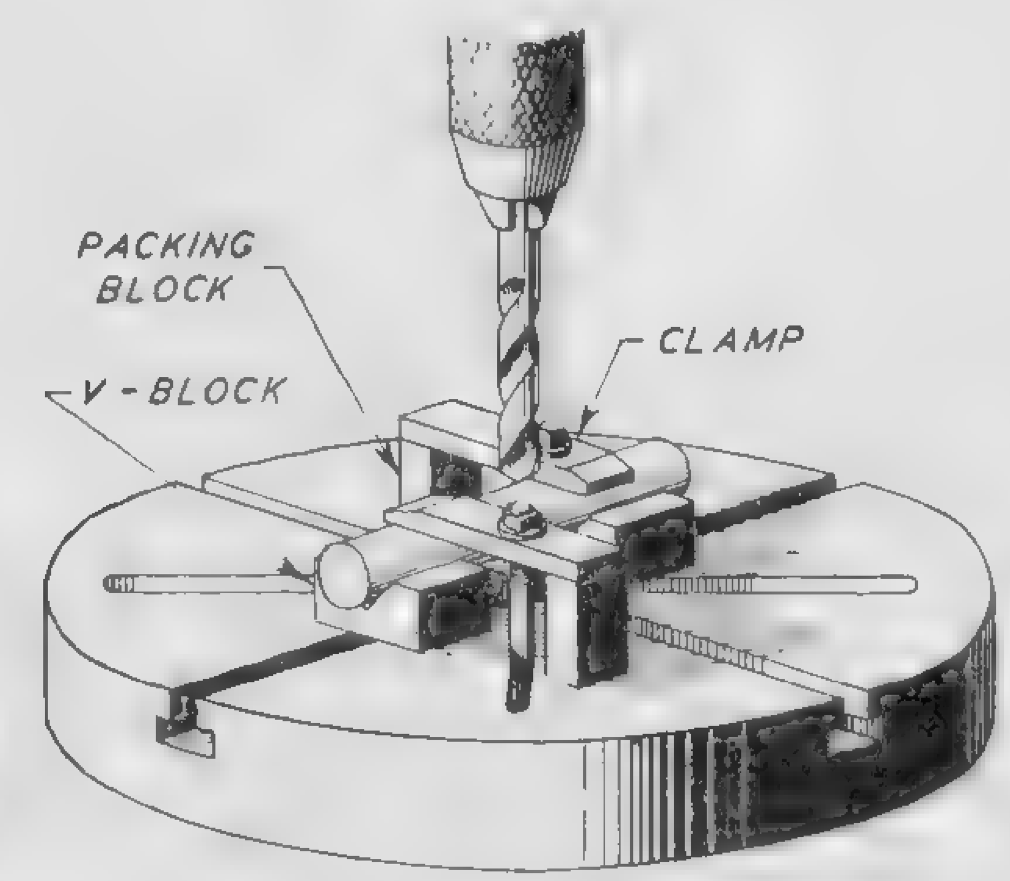



Fig. 15. Work Mounted and Clamped on V-Blocks

**MOUNTING WORK ON DRILL PRESS TABLE.** The table should be kept free of pits and roughness by intelligent mounting of the work

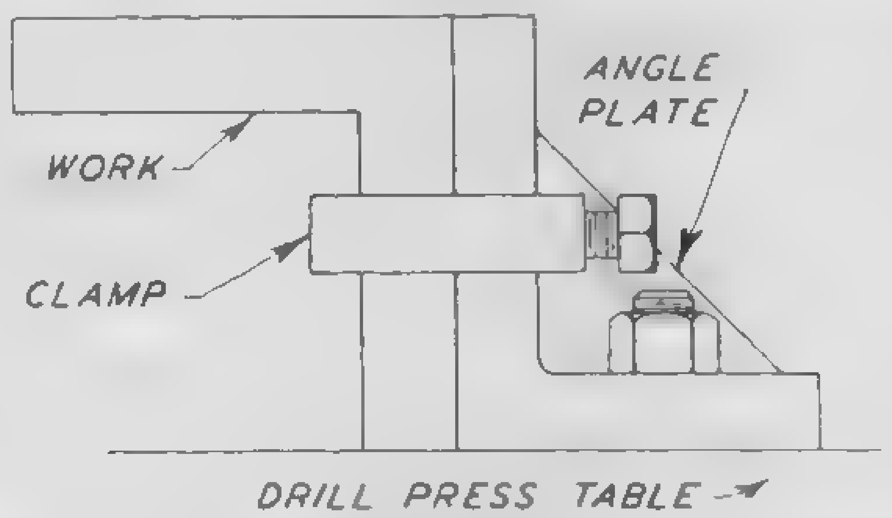



**Fig. 16. Clamping Work to Table with the Help of an Angle Plate**

to be drilled. Even though there are slots and a center hole in the table, it is good practice to elevate the work on parallels whenever possible. Holes going only part way through the metal sometimes find their way entirely through and into the table; hence, good judgment will be exercised if the work is placed on parallels. **V**-blocks are necessary to support round stock. Examples of workmanlike mountings are shown in Figs. 13 through 16.

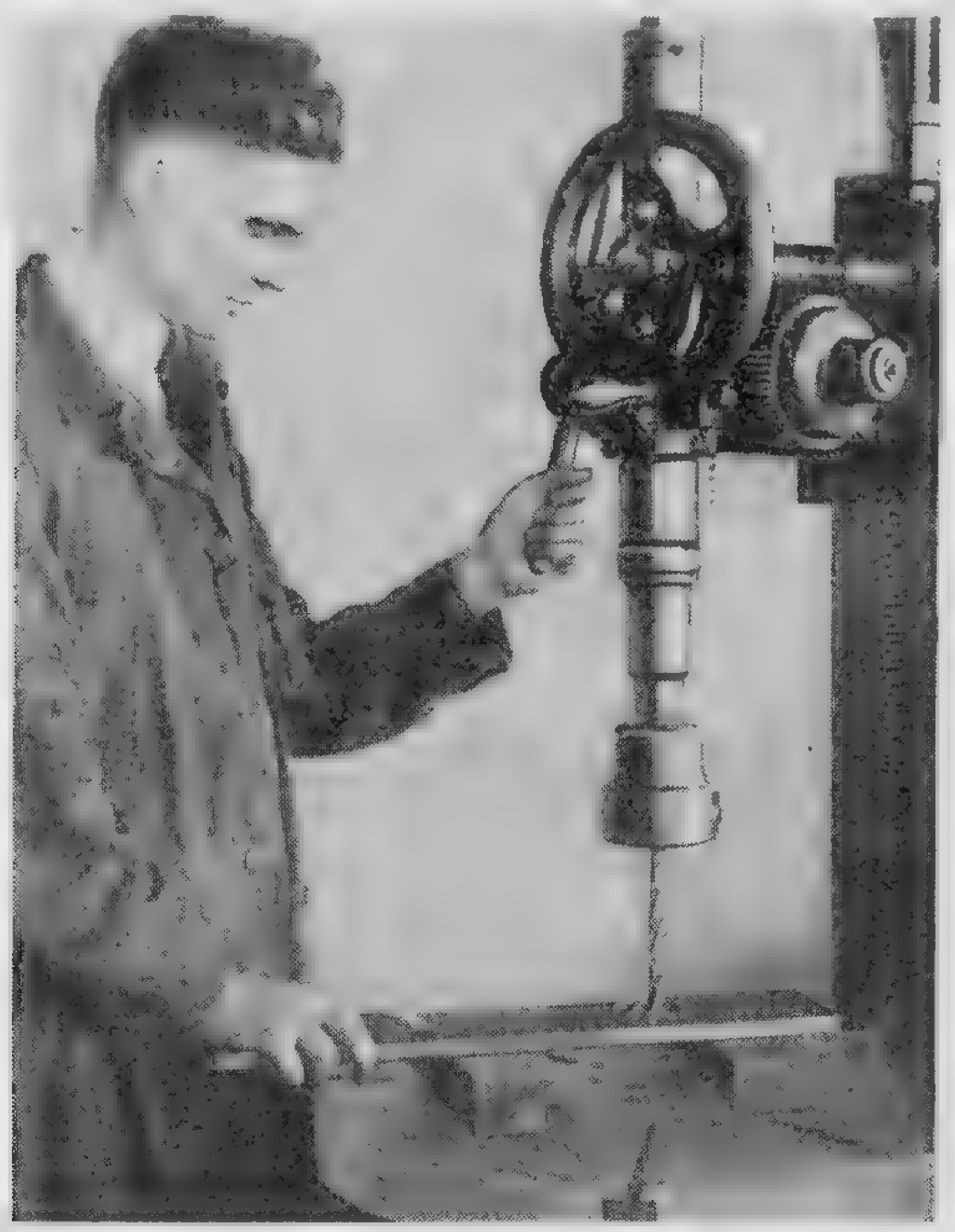


**Fig. 17. Clamp Work Rigidly—Do Not Hold it**
**Work should never be held by hand. It should always be clamped rigidly.**
*Courtesy of The Cleveland Twist Drill Co., Cleveland, Ohio*





The necessity of securely fastening the job to the table cannot be too strongly emphasized. Many injuries have been caused by holding the work in the hand, as shown in Fig. 17. A stop on the table will prevent the work from turning; but as the drill breaks through, it may dig in and break the drill. Both the table and the table bracket must be tightly clamped before drilling. Movement of the table after drilling has started will result in drill breakage and possible injury to the operator. The bolts should be placed as near the work as possible. Remember, the piece to be drilled requires security and rigidity, rather than the packing blocks.

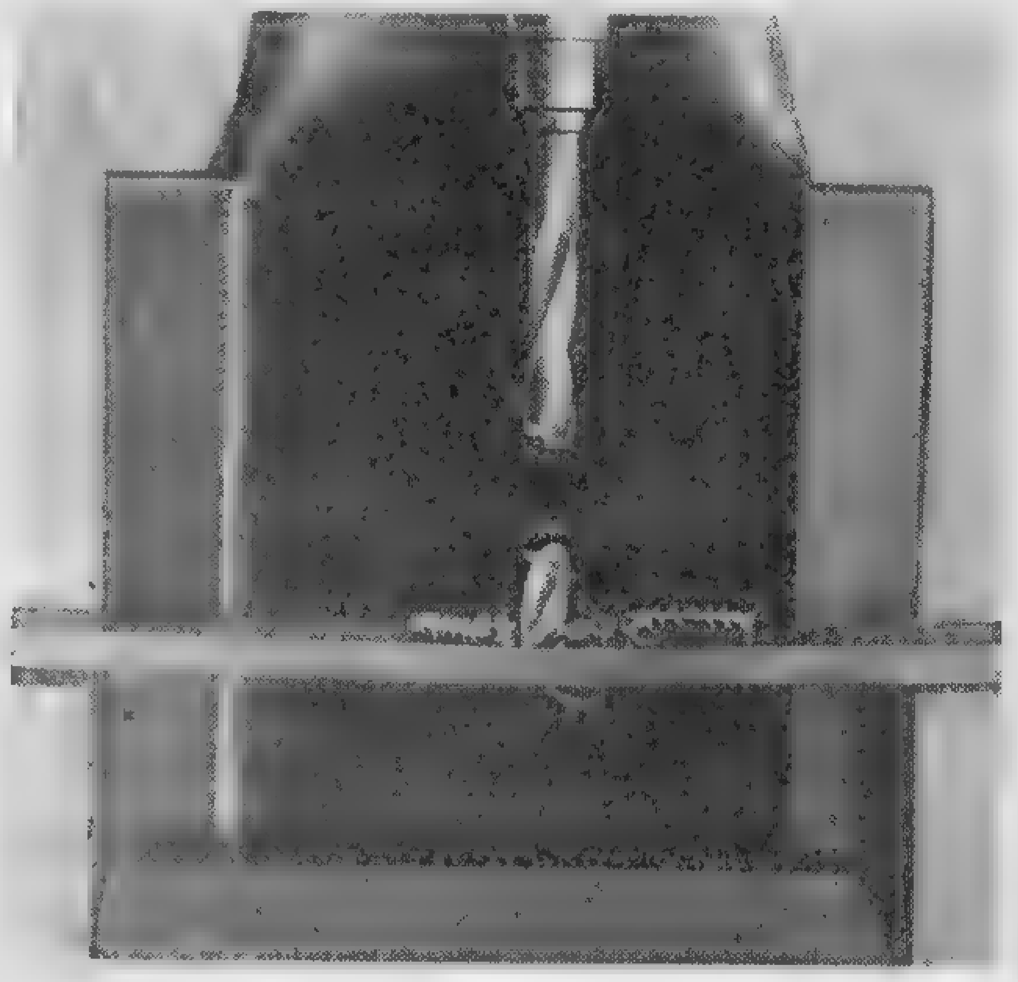


**Fig. 18. A Broken Drill—The Result of Spring**
*Courtesy of The Cleveland Twist Drill Co., Cleveland, Ohio*

Care is necessary in placing the parallels, also. They should give good support to the work. Fig. 18 shows what happens when the parallels are too far apart which allows the work to spring and bind the drill.

A well-mounted job reflects the operator's mechanical ability and judgment. Select bolts which are just long enough, clamps of the right type and size, packing blocks of the correct height, washers for all nuts, make sure that the job is securely clamped, and the drilling work will be off to a good start.

## QUESTIONS

*1. Is it necessary to clamp the work securely for drilling?*
*2. Name several methods employed to hold work.*
*3. What are parallels and why are they used?*
*4. What is an angle plate?*

5. *V-blocks are used for what kind of stock?*
6. *Name and describe several types of clamps or straps.*
7. *What is a step block and how is it used?*
8. *In what position relative to the table should the clamps be arranged?*
9. *What should be the location of the bolts with respect to the work?*
10. *How is a drill press table protected from drill damage?*
11. *How should parallels be placed for best support?*

## STEP 3—SELECTION AND CARE OF DRILLS

**TYPES OF DRILLS.** Drills are manufactured in a great variety of sizes and shapes. The flat drill was used exclusively in the early days of machine work, but has given way to the more efficient twist drill of the type shown in Fig. 19. Twist drills are made by forging the drill to the approximate size and milling and grinding to the finished size. Spiral flutes are found on most drills, but straight fluted drills are used to some extent for soft metal drilling.

Drills are provided with several types of shanks. Straight and taper shank drills, shown in Fig. 20, are perhaps most common. Taper square shanks for braces, grooved shanks for special chucks, threaded

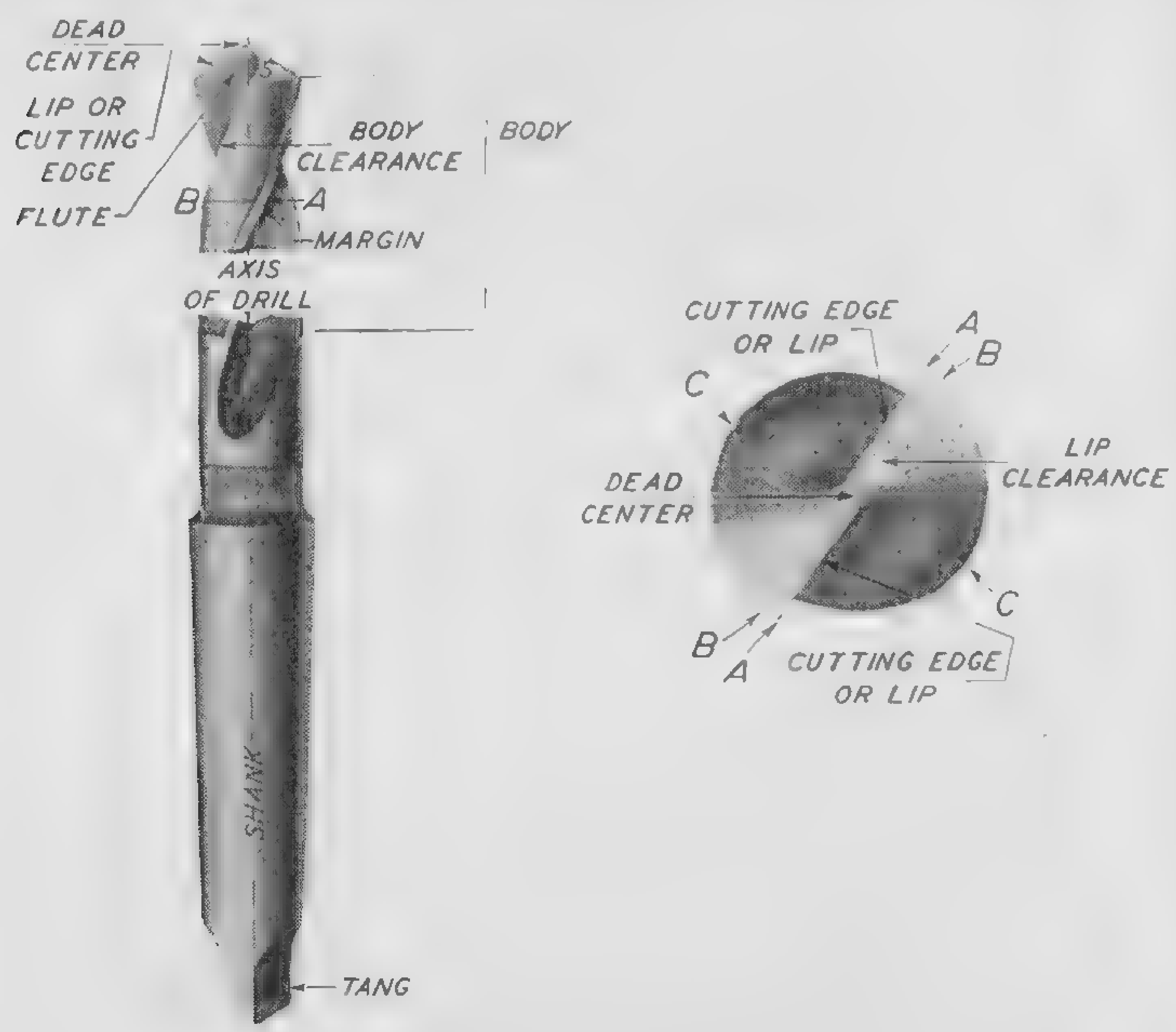



Fig. 19. The Parts of a Twist Drill
The Point *A-B* Is the Margin. It Is the Full Diameter of the Drill. *B-C* Is Body Clearance
*Courtesy of The Cleveland Twist Drill Company, Cleveland, Ohio*





shanks, and flatted shanks are manufactured for special purposes. The standard Morse taper has been universally adopted for twist drills of the taper shank variety.

**DRILL DESIGNATIONS.** As to size, drills are identified in three ways: Number, letter, and fraction. Millimeter sizes may be purchased for special work. The number sizes run from No. 80 to No. 1 (.0315″ to .228″); letter sizes from "A" to "Z" (.234″ to .413″); fractional sizes from 1/64″ upward by 64ths. Sizes are checked with a drill gage like the one shown in Fig. 21. High speed drills, designated by the two words High Speed, HS, or HSS near the size marking, are used almost entirely in rapid production work because they may be run at three times the speed of carbon drills.

Drills with cemented carbide cutting lips are used at very high speeds for drilling nonferrous metals, but are not so practical for cast iron and steel because the carbide tips are not so well reinforced as are lathe, shaper, and other types of carbide-tipped tool bits.

**GRINDING AND ADJUSTMENT OF DRILLS.** If any one feature of machine shop work could be pointed out as more important than any other, it might very well be the ability to grind and adjust cutting tools, and this is not small in scope. It would include hand tools as

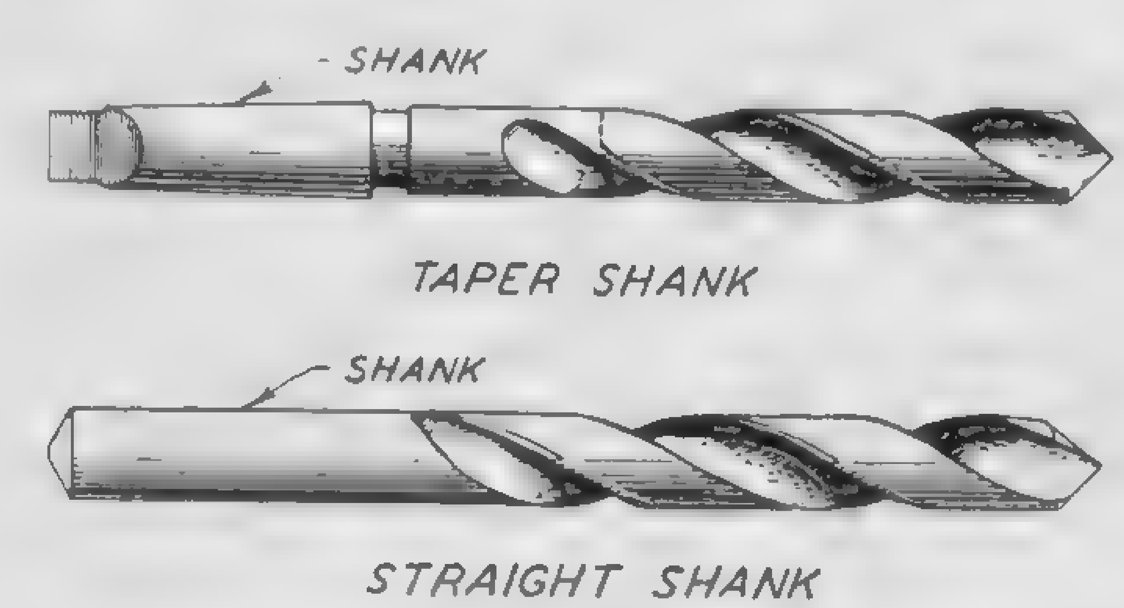



Fig. 20. Twist Drills

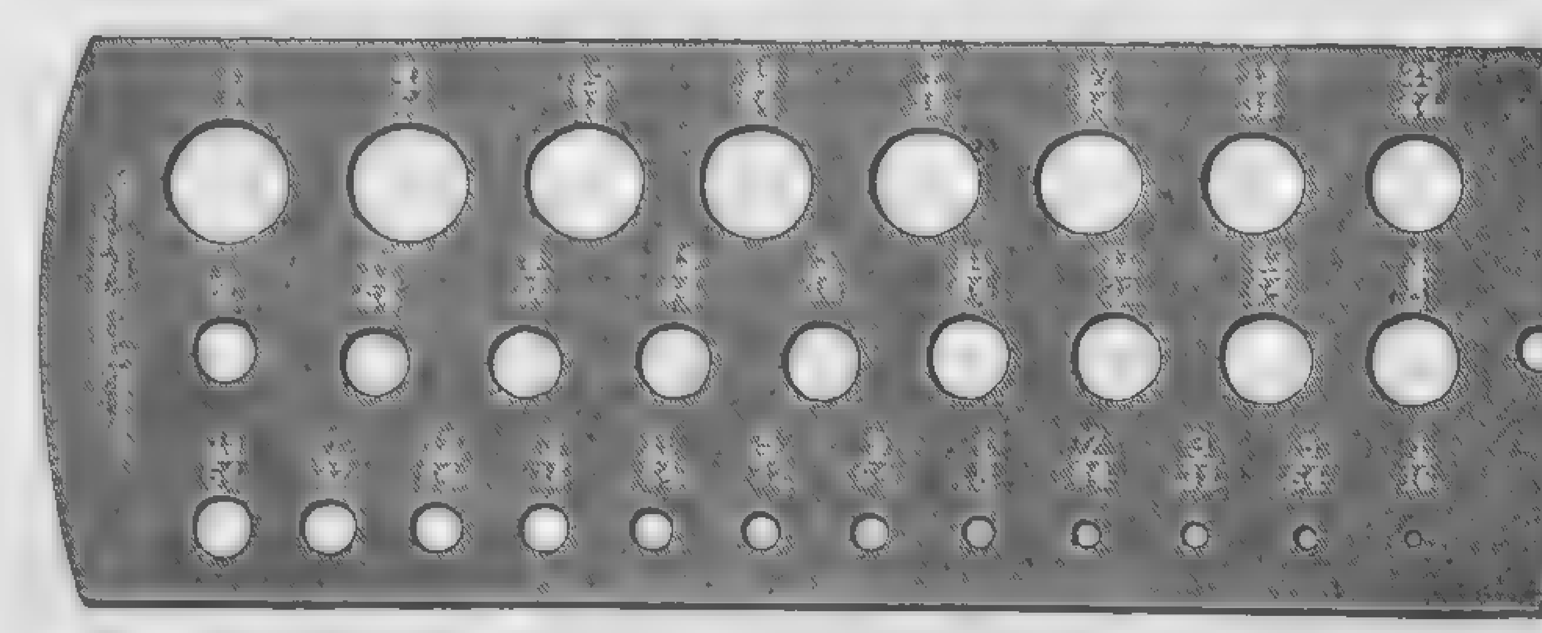


Fig. 21. Twist Drill Gage
*Courtesy of Morse Twist Drill & Machine Co., New Bedford, Mass.*

well as machine tools. Possessing that ability, a workman could proceed with confidence on almost any task to which he might be assigned in the shop. Of extreme importance to the drill press operator is the matter of diagnosing drilling troubles and providing the remedy. The ability to grind drills cannot be learned from a book but requires considerable practice.

The four things to consider when one is grinding a drill are as follows:

1. Centralize the point, since a point ground off center will cause an oversize hole. The point should be carefully checked with a drill point gage, Fig. 22.

2. The angle of the cutting lips should be 59°, see Fig. 23. This angle also can be tested with the drill point gage.

3. The heel or lip clearance angle for best drilling results should be about 12°, as in Fig. 24. This angle is sufficient for clearance and it still provides plenty of metal to give support to the cutting edge.

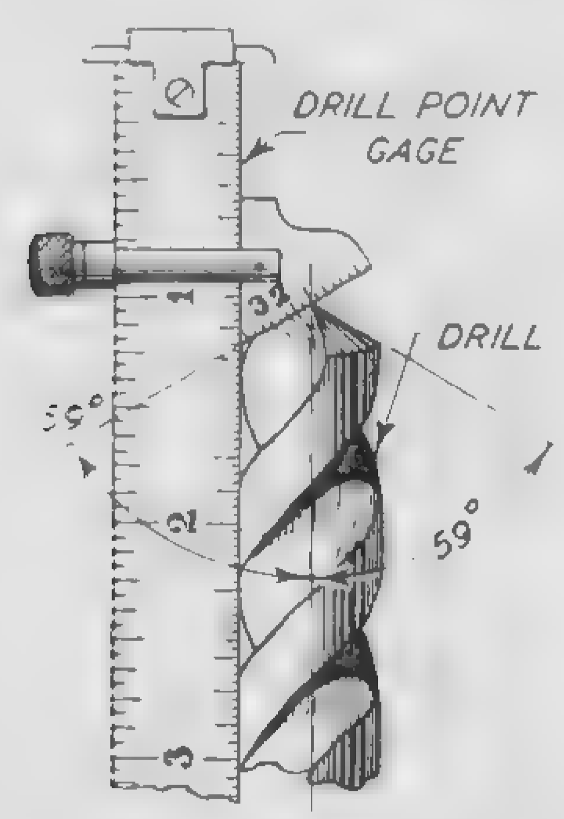



Fig. 22. Using Drill Point Gage

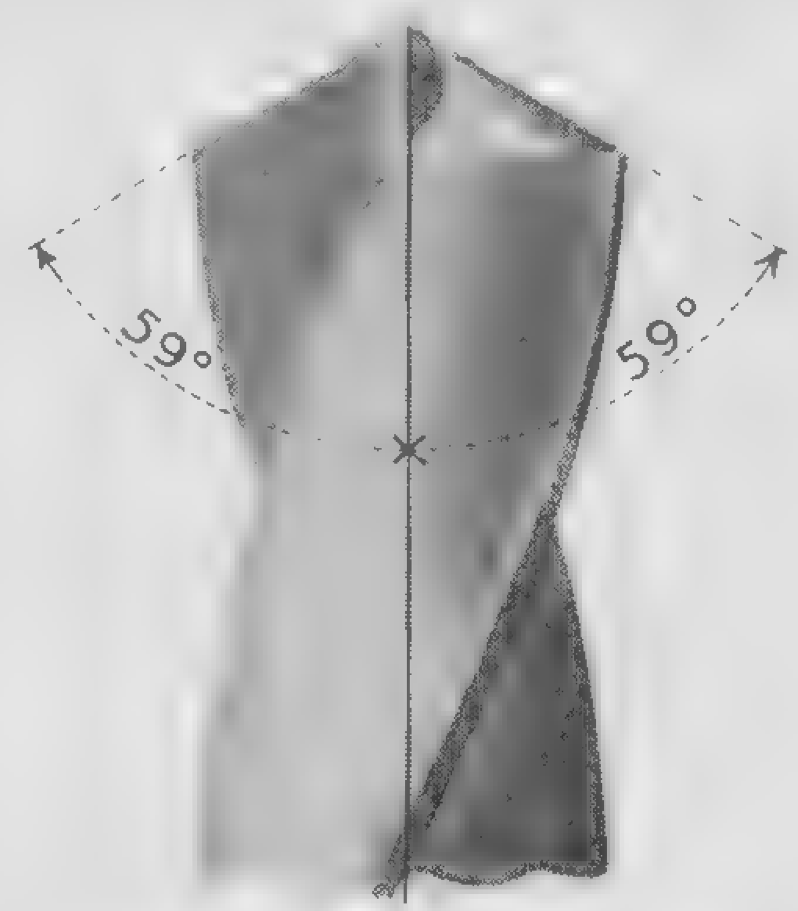



Fig. 23. Lips Ground Correctly

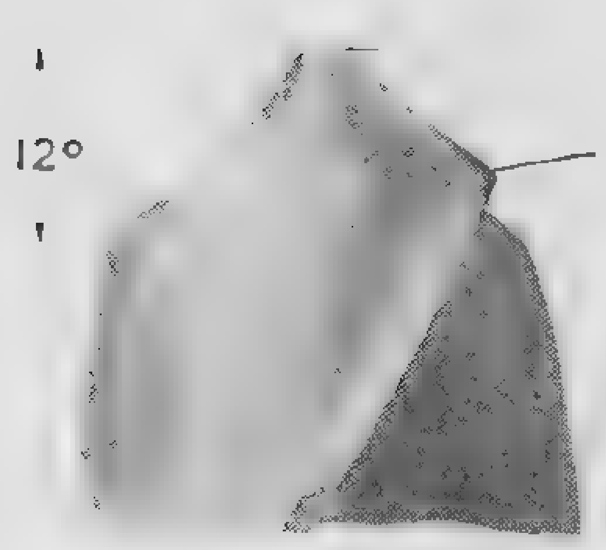



Fig. 24. Correct Lip Clearance Angle

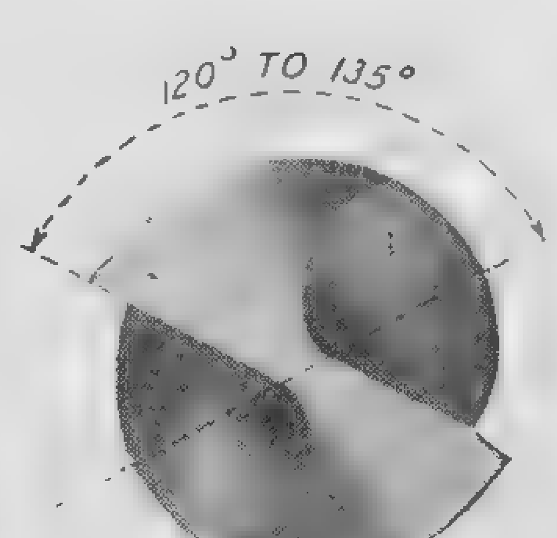



Fig. 25. Another Way to Gage Lip Clearance

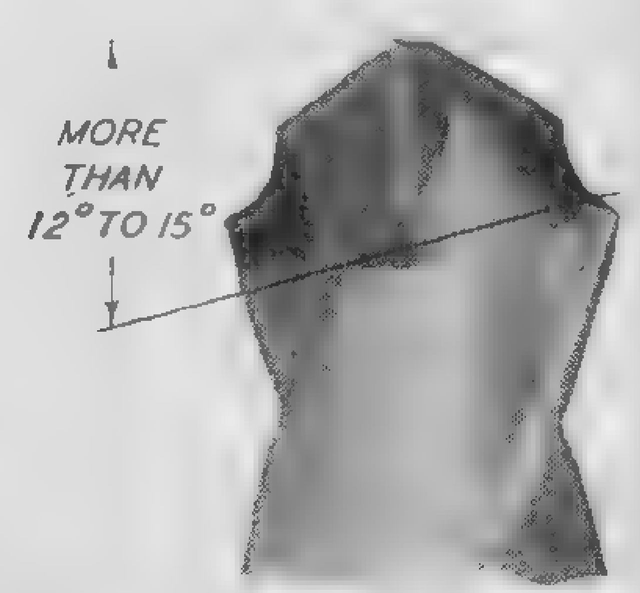



Fig. 26. Result of Too Much Lip Clearance

*Courtesy of The Cleveland Twist Drill Co., Cleveland, Ohio*





4. Lastly, the edge or web must be ground slightly to the right as indicated in Fig. 25. This provides the correct lip angle clearance and

Fig. 27. Result of Insufficient Lip Clearance
*Courtesy of The Cleveland Twist Drill Co., Cleveland, Ohio*

is important for accurate drilling. Figs. 26 and 27 show the results of faulty lip clearance.

**CORRECT AND INCORRECT METHODS IN GRINDING DRILLS.** Common mistakes in drill grinding are: too much heel clearance thus weakening the cutting edge, point off center resulting in an oversize hole, insufficient lip clearance which may cause the drill to split, lips ground at different angles giving an irregular hole and causing the

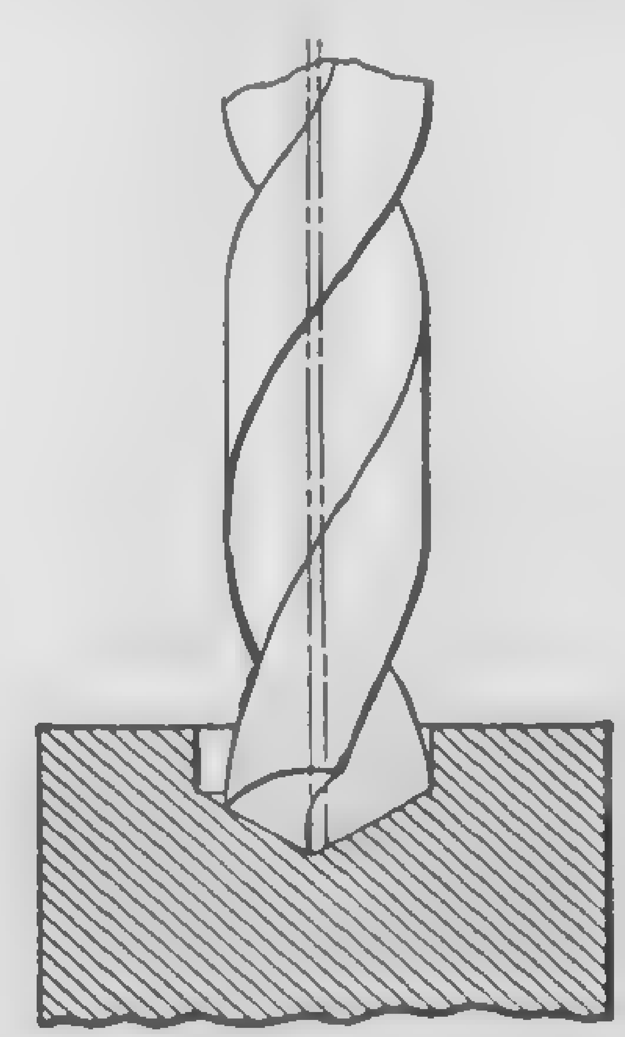


Fig. 28. Drill with Lips of Unequal Length

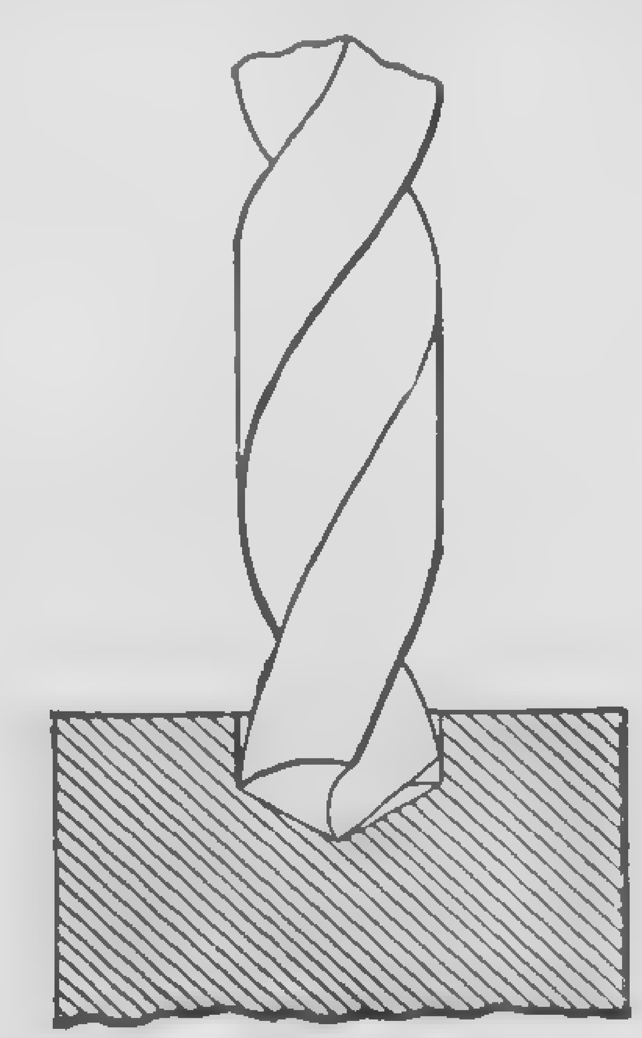


Fig. 29. Drill with Lips of Unequal Angles

drill to rotate on two centers. Figs. 28 and 29 illustrate two results of incorrect grinding of drills.

An included angle on the lips of 118° is considered the best for general duty drilling, Fig. 23. But, when unusually hard metal is to be drilled the angle on the lips should be increased to between 125° and 150°. For soft metals, the lip angle may be decreased to approximately 90° or less. These angles can be gaged accurately with a bevel protractor.

To provide sufficient strength in the drill, the thickness of the web increases toward the shank end. Consequently, as the drill

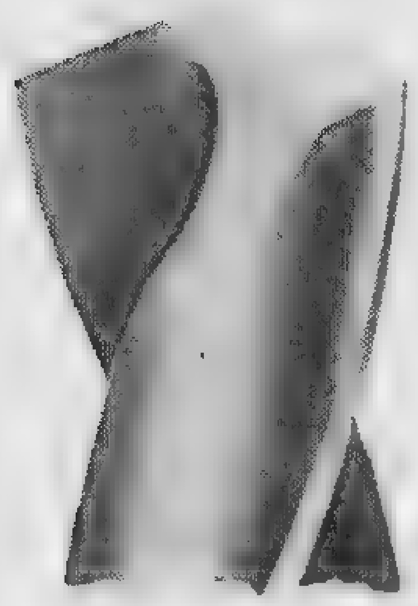


Fig. 30. "Notched Point" Web Thinning

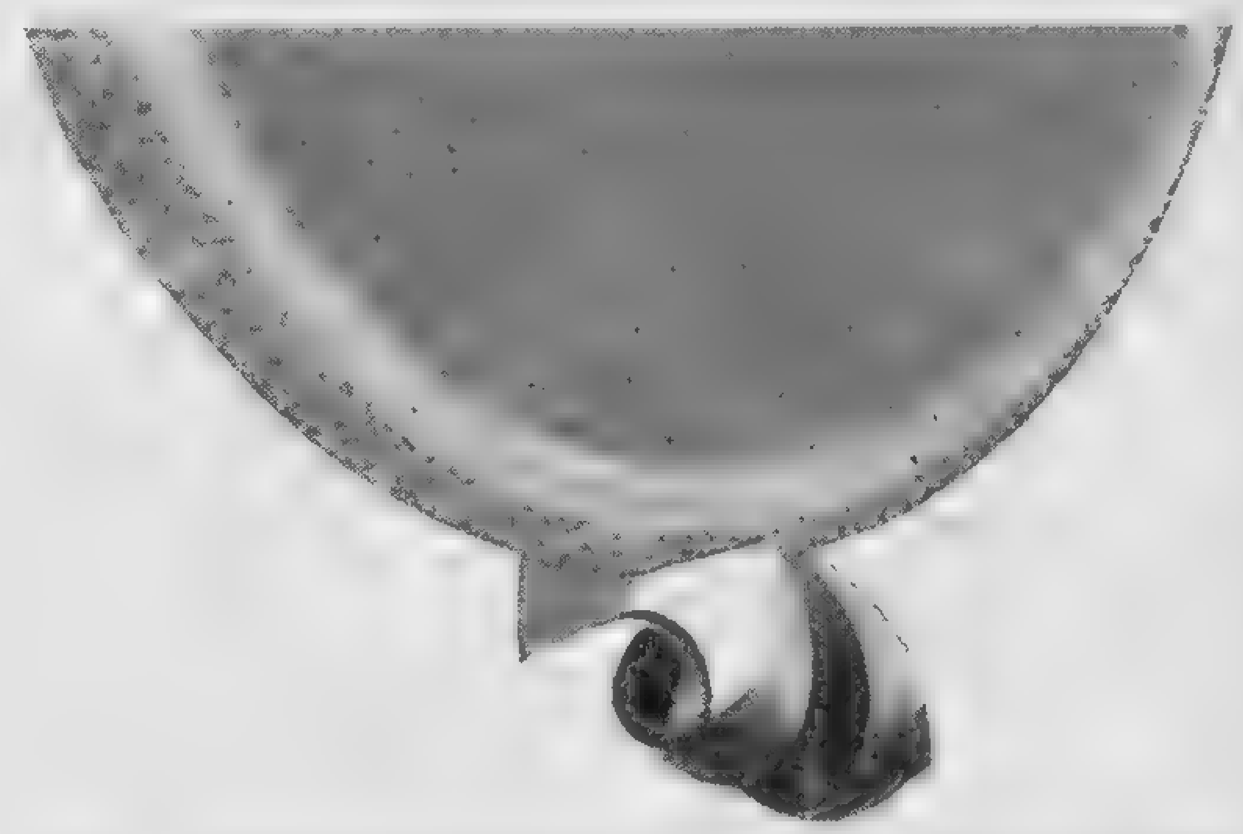


Fig. 31. Thinning the Web on a Round-Faced Emery Wheel

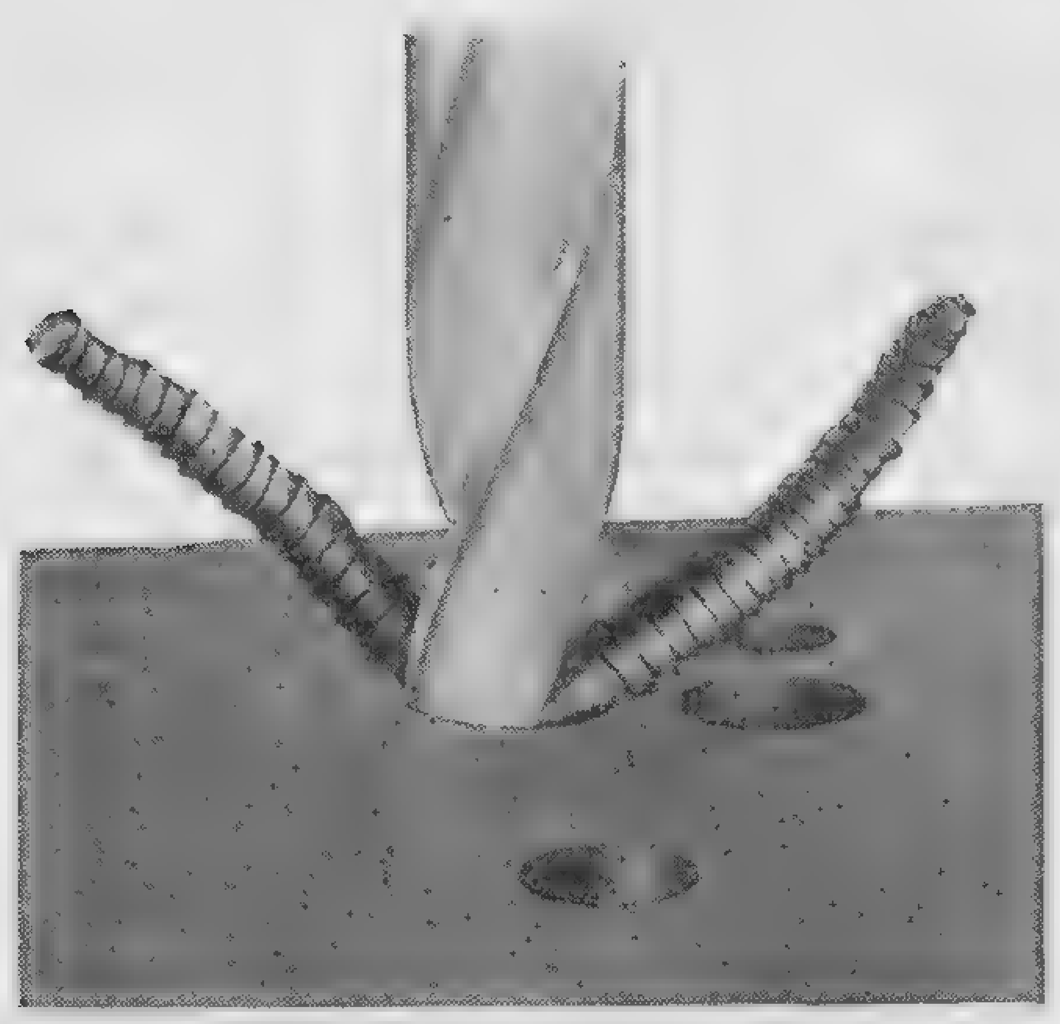


Fig. 32. Properly Rolled Chips From a Well Ground Drill
*Courtesy of The Cleveland Twist Drill Co., Cleveland, Ohio*





becomes shorter, it is necessary to thin out the web, Fig. 30. This operation is performed on the edge of the emery wheel as indicated in Fig. 31.

A well-ground drill will turn out two closely rolled chips, as shown in Fig. 32. This type of chip prevents clogging of the hole and results in excellent elimination of the drilled material. Do not neglect the application of a coolant when you start the job of drilling steel and wrought iron.

**HOW TO GRIND A DRILL.** Upon selecting the proper drill size for any particular job, the operator should make sure that he has received the correct size from the tool room. Next, examine the point and also the shank of the drill. Rough shanks and broken tangs will give trouble. The uneven shank will cause the drill to wobble, and a broken tang will make its removal from the sleeve or spindle a laborious job. The drill is likely to slip in the sleeve while drilling as the tang provides about 40 per cent of the holding ability of the setup. The tapered shank is responsible for the other 60 per cent.

Dull cutting edges on any cutting tool will appear "shiny" and this is a clue to the condition of the tool. A sharp edge will reflect no

Fig. 33. How to Grind a Drill

light. Dressing the point of the drill, as shown in Fig. 33, is accomplished as follows:

1. Grasp the shank of the drill with the right hand and rest the body of the drill in the left hand.

2. Place the fingers of the left hand supporting the body of the drill upon the grinder rest.

3. Stand at approximately 59° with the face of the stone and a bit to the left of the wheel.

4. Touch the drill lip to the grinding wheel in, roughly, a horizontal position.

5. With the left hand acting as a fulcrum, pivot the drill downward with the right hand. Light pressure should be applied to the cutting lip and the pressure increased as the heel is reached. This will avoid burning the lip and will assure proper heel clearance.

6. Repeat this process two or three times and then revolve the drill a half turn and apply the same procedure to the other lip. To prevent the drill from overheating, quench often in water.

7. Test with the drill point gage and continue grinding until a satisfactory point is obtained.

**Note:** Always grind from lip toward heel.

Precision drill grinding is possible only with a drill-grinding machine, similar to the one shown in Fig. 34. Where a large amount of

**Fig. 34. Drill Grinding Machine**
*Courtesy of The Hisey-Wolf Machine Co., Cincinnati, Ohio*

grinding is done, this machine is an economical factor. These are made as a special type machine as shown, or attachments may be secured for attaching to an ordinary grinder.



# The Engine Lathe

The engine lathe is the most commonly used machine tool. A greater variety of work can be done on it than on any other machine. It is power driven; it has automatic feeds, interchangeable speeds, and has a lead screw for cutting threads.

Engine lathes are used for boring, turning, cutting, chasing threads, polishing, and screw cutting. The work can be held in the chuck, on the faceplate, or between centers.

Lathes have changed greatly both in design and appearance; however, the fundamental principles of design, construction, and operation remain the same. As a result, a thorough understanding of the work and of the lathe makes it possible for a skilled worker to operate any lathe of this type, regardless of its age or make.

## PRINCIPAL MECHANICAL FEATURES OF THE LATHE

**BED.** The bed has horizontal ways for insuring accurate work. The ways should be kept clean and oiled daily. Tools, such as files, wrenches, cutting tools, etc., should never be placed directly on this part of the machine. They should be placed on a suitable board, which is placed across the ways of the machine or on a convenient table. Typical modern lathes, with parts indicated, are shown in Figs. 1 and 2.

**HEADSTOCK.** The headstock is secured permanently to the ways at the left-hand end of the machine. It contains the main working spindle, the gears, and the speed-change levers. Full directions as to setting the proper speeds and feeds are always given on a chart fastened permanently to the machine near the feed change or gear levers.

A hole extends through the entire length of the main working spindle. This hole is bored tapered at the front end to receive the live center.

**TAILSTOCK.** The tailstock, at the right-hand end of the lathe, is adjustable along the ways to accommodate different lengths of work. The tailstock consists of the tailstock spindle, spindle wheel, spindle clamp, clamp bolt, and tailstock center. The tailstock spindle is also bored tapered to receive the dead center.

**CARRIAGE.** The carriage is movable along the ways either by hand or power, which is transmitted to this part of the machine from the feed mechanism by the lead screw. It contains the saddle, apron,

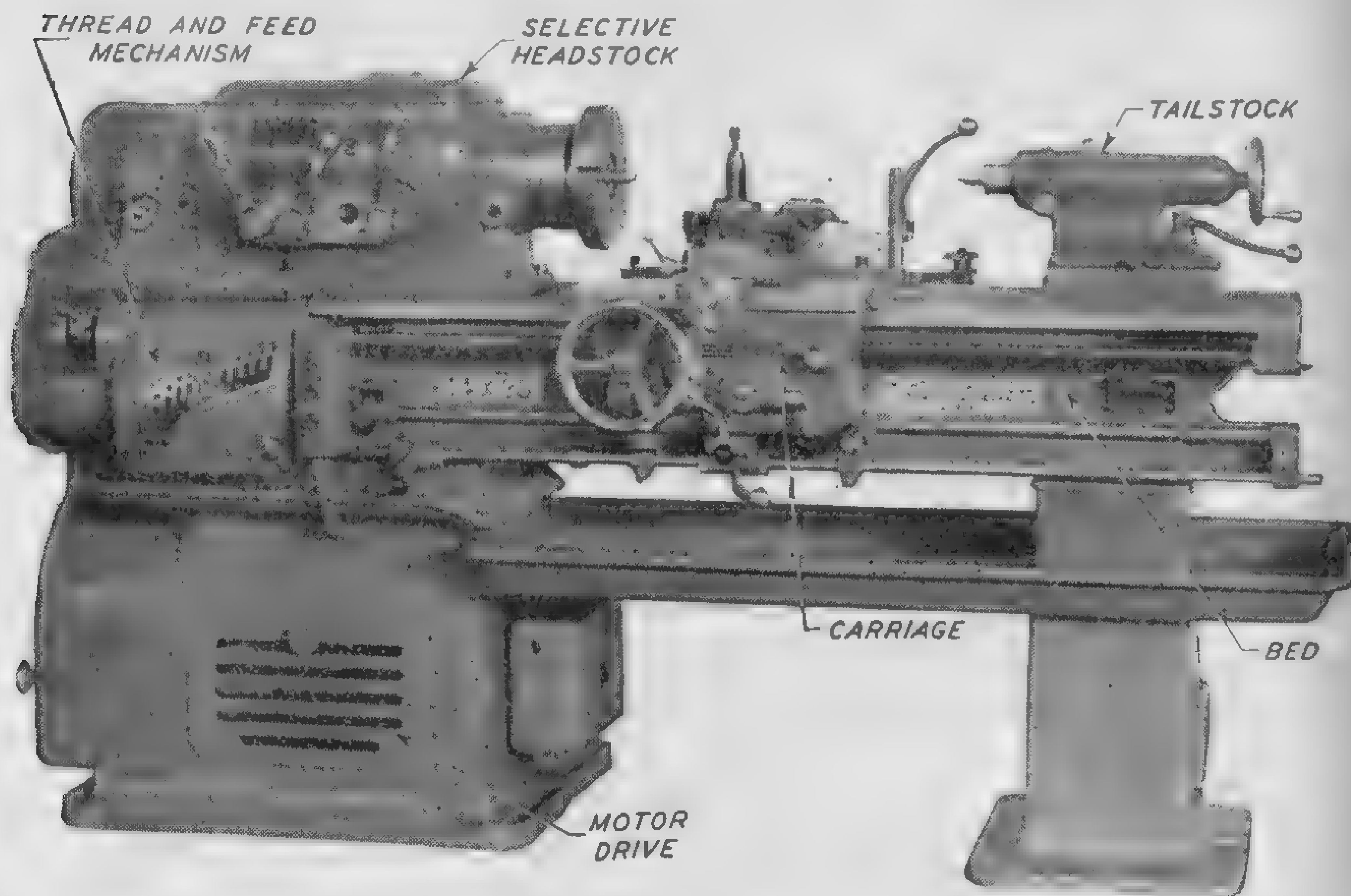



Fig. 1. Principal Parts of a Modern Engine Lathe
*Courtesy of Hendey Machine Co., Torrington, Conn.*

longitudinal and cross-feed mechanism, and the compound rest which supports the tool-post.

**FEED MECHANISM.** The feed mechanism, located at the left-hand end of the machine, regulates the amount the tool moves during one revolution of the spindle.

## FUNDAMENTALS OF LATHE OPERATION

**LATHE CENTERS.** The shanks of the lathe centers are tapered to fit tapered holes in the spindle. This is usually a Morse standard taper. If any dirt, chips, or burrs are on the taper shank or in the spindle, the live center will not run true. The center and the spindle





hole should be cleaned thoroughly before the centers are put into the holes. The dead center (located in the tailstock) is hardened while the live center is not.

**HOW TO REMOVE THE LIVE CENTER.** To remove the live center, place a knock-out bar through the hollow spindle of the headstock. The center can then be bumped out. Do not let the center strike

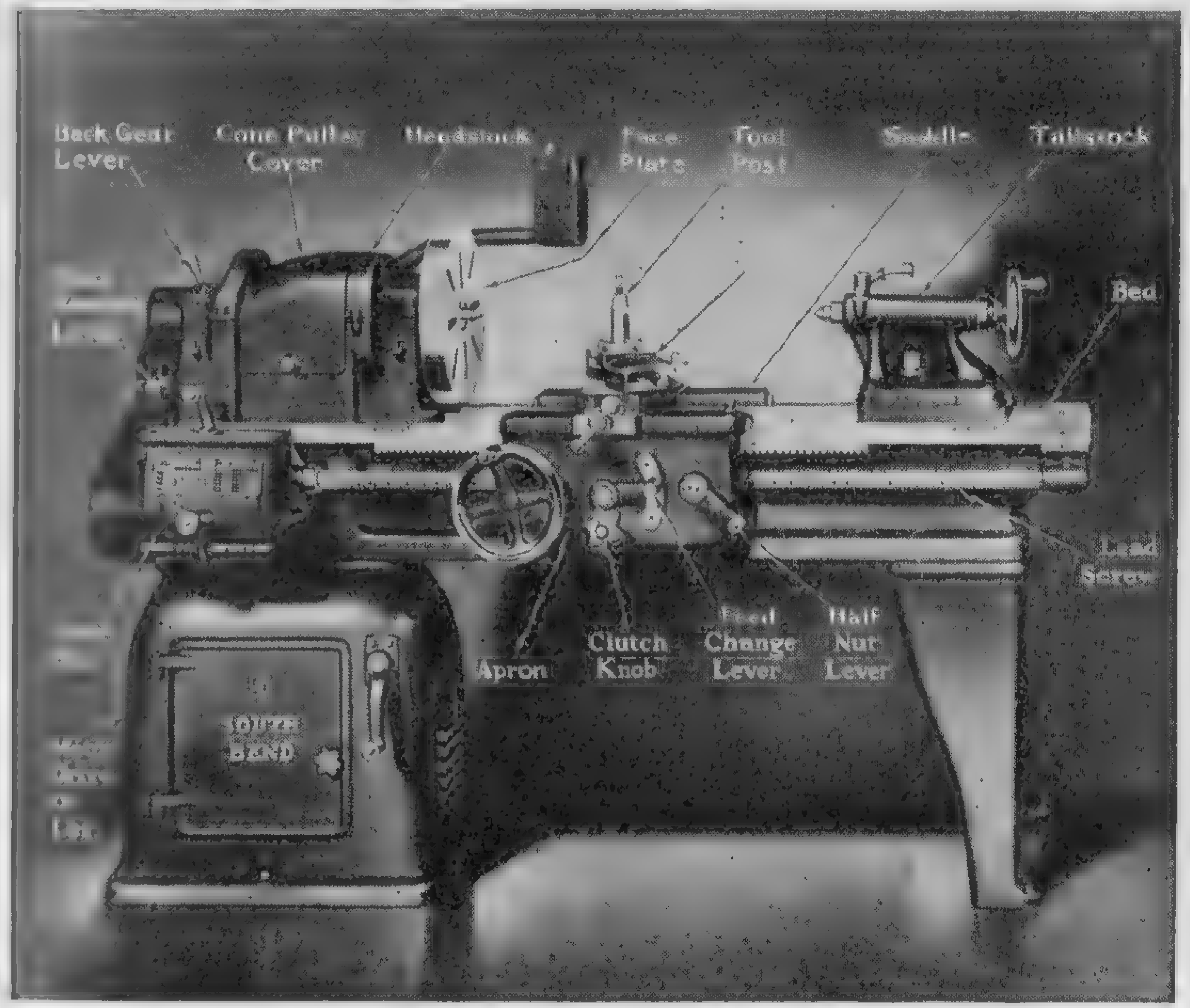



Fig. 2. Operating Parts of a Modern Lathe
*Courtesy of South Bend Lathe Works, South Bend, Ind.*

the machine when removing it, as this is likely to injure the center or the machine.

**HOW TO REMOVE THE DEAD CENTER.** Turn the tailstock spindle wheel "back" until the end of the screw hits the end of the center and forces out the dead center.

**REGULATING THE SPEED OF A LATHE.** Metals should be turned as rapidly as possible, but not so rapidly that the tool will become dull too quickly. The best speed at which to turn depends upon a number of factors. These will be considered fully later.

**CUTTING SPEED.** Cutting speed refers to the surface speed of the work being turned; hence, the diameter of the work determines the number of revolutions per minute (r.p.m.) at which the lathe spindle must be run. For example, a 2-inch shaft must be turned at twice the r.p.m. as a 4-inch shaft to obtain the same surface speed.

The surface speed can be regulated to suit any material or turning operation by a mechanism designed for this purpose on the lathe. The range of speeds may vary from 15 r.p.m. to over 400 r.p.m.

Although the cutting speeds are often difficult to determine, even a beginner should try to operate the lathe at a speed and feed which conform to good practice.

**HOW TO REGULATE THE SPEED ON A GEARED-HEAD LATHE.** On the American Pacemaker Lathe only two levers are used to secure

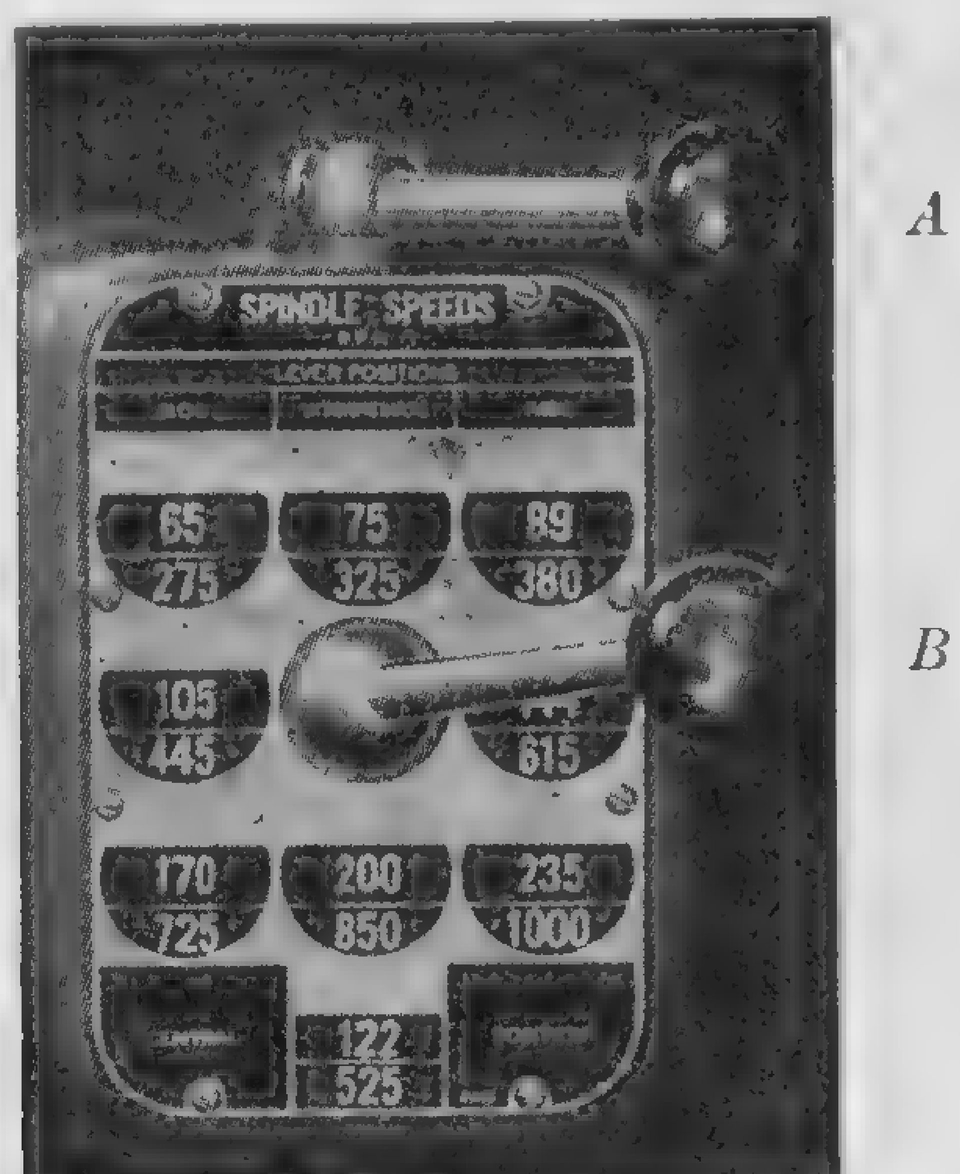



**Fig. 3. Direct Reading Speed Control on American Pacemaker Lathe**
*Courtesy of American Tool Works Co., Cincinnati, Ohio*

the entire range of spindle speeds. These levers are direct reading, thus eliminating the necessity of the operator referring to speed or index plates or even of keeping lever positions in mind while changing speeds. With this control, speed changes are made instantly.

Speed changes are controlled by the two levers *A* and *B*, shown in Fig. 3. The positions of these levers indicate the spindle speed in





r.p.m. The spindle speed plate has the following three colors: blue for slowest; red for intermediate speed; black for fast speed.

The top lever *A* has three positions; namely, slow, intermediate, and fast range.

The lower lever *B* has nine positions, each designated by a circle showing three spindle speeds: slow, intermediate, and fast. The slow speeds, at top of circles, do not show in Fig. 3.

The position and color of the top lever *A* shows which one of these speeds will be obtained for any position of the bottom lever *B*. Fig. 3 shows the levers set for a speed of 615 r.p.m. since the knob of lever *B* is over the circle reading 615, and lever *A* is over the fast speed range.

If lever *B* is not moved but kept exactly in the position where it is, but if lever *A* is moved to the extreme left to the slow speed range, then a speed of 34 r.p.m. is secured. Moving lever *A* to the central or intermediate speed range would obtain the intermediate speed of 144 r.p.m.

But suppose lever *A* is placed over the fast range, and lever *B* is placed in the lower right-hand circle reading $\begin{matrix}55\\235\\1000\end{matrix}$; then the speed becomes 1000 r.p.m.

**HOW TO REGULATE THE SPEED ON A BELT-DRIVEN BACK-GEARED LATHE.** With this type of lathe, the speed changes are made by placing the driving belt on different steps of the cone pulley and also by the use of back gears, Fig. 4. The cone pulley can be connected with the spindle by engaging the locking pin. When the cone pulley is locked to the spindle, three speeds may be secured with the headstock shown in Fig. 4 by placing the belt on the different steps of the pulley. The smaller the step the faster the speed.

Three speeds can be obtained by driving directly from the cone pulley to the spindle without the gears in mesh.

Three slower speed changes can be obtained by meshing in the gears and driving the spindle through them. Hence a lathe with a three-step pulley will have three speeds in direct drive and three speeds in the gear drive, making a total of six speed changes.

The back gears are meshed in as follows:

1. Stop the machine.

2. Disengage the locking pin. When the locking pin is disengaged, the cone pulley will run freely without moving the spindle.

3. Engage the back-gears by pulling the handle forward. On

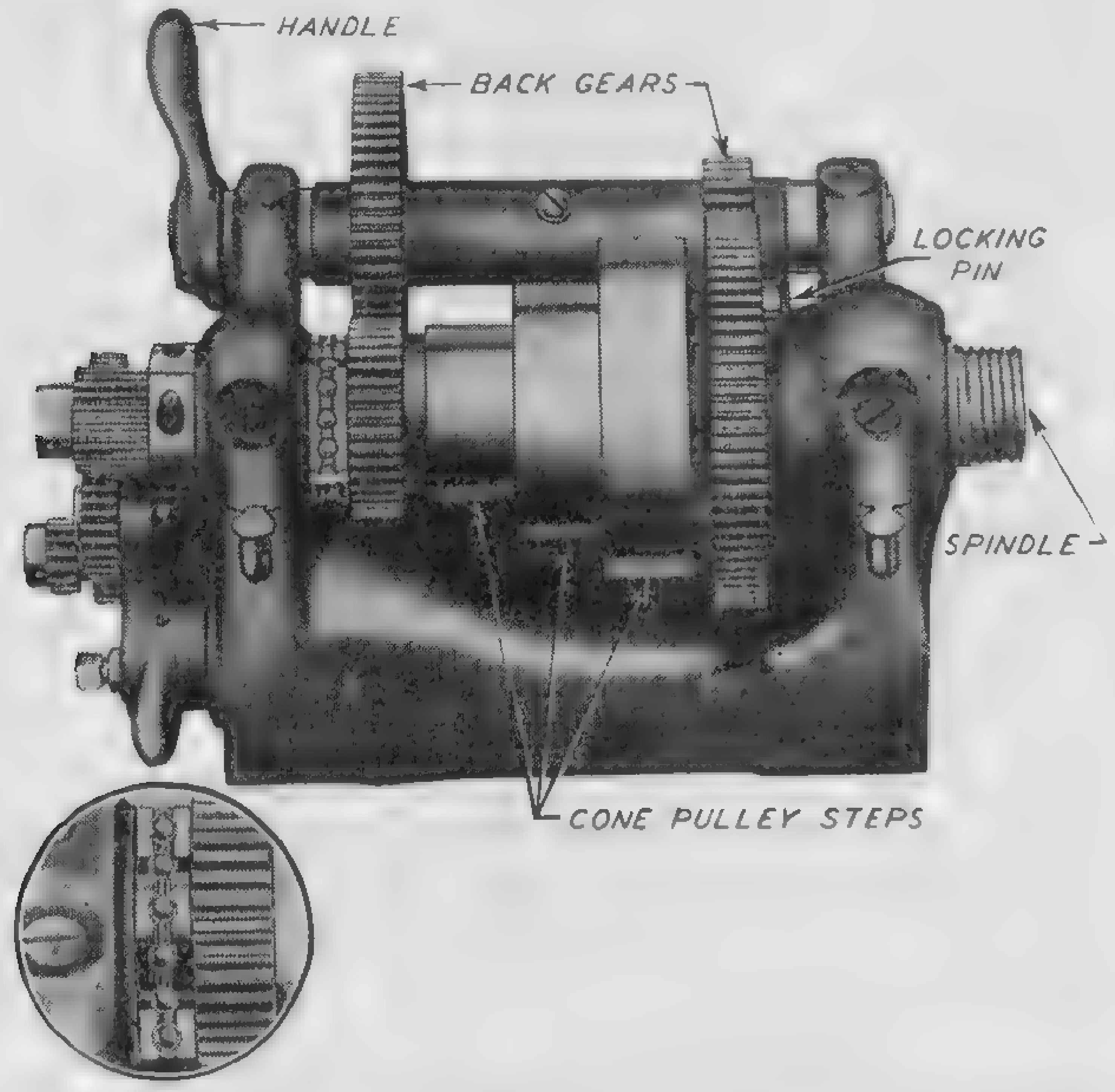



**Fig. 4. Plan of Lathe Headstock Showing Cone Pulley and Back Gears**
*Courtesy of South Bend Lathe Works, South Bend, Ind.*

this type of lathe the r.p.m. must be determined with a speed indicator or revolution counter.

**FEED.** Feed refers to the distance that the tool moves during each revolution of the work. Rate of feed can be expressed in the following two ways:

1. The actual tool movement per revolution of the work may be given in thousandths of an inch. For example, the range of feeds may be given as .004 to .0208.

2. Feed range also may be indicated by the number of cuts per inch. This might be said to be 10 to 400.

The feed is regulated to suit the kind of stock, depth of cut, and finish desired. Feed-changing mechanisms vary considerably, but to determine the proper adjustments is relatively easy.

**The Longitudinal Feed.** The feed is usually made to go in the direction of the live center, in other words, from right to left. This





creates the greatest pressure against the live center which revolves with the work. The feed is made to work by engaging the feed locking lever.

**THE CROSS-FEED MICROMETER DIAL.** The cross-feed micrometer dial, Fig. 5, is one of the precise measuring instruments at the command of the lathe operator. There is no need for guess work when taking a cut on a piece of work in the lathe.

The graduations on the dial are in thousandths of an inch, but the operator must remember when using the dial that when the

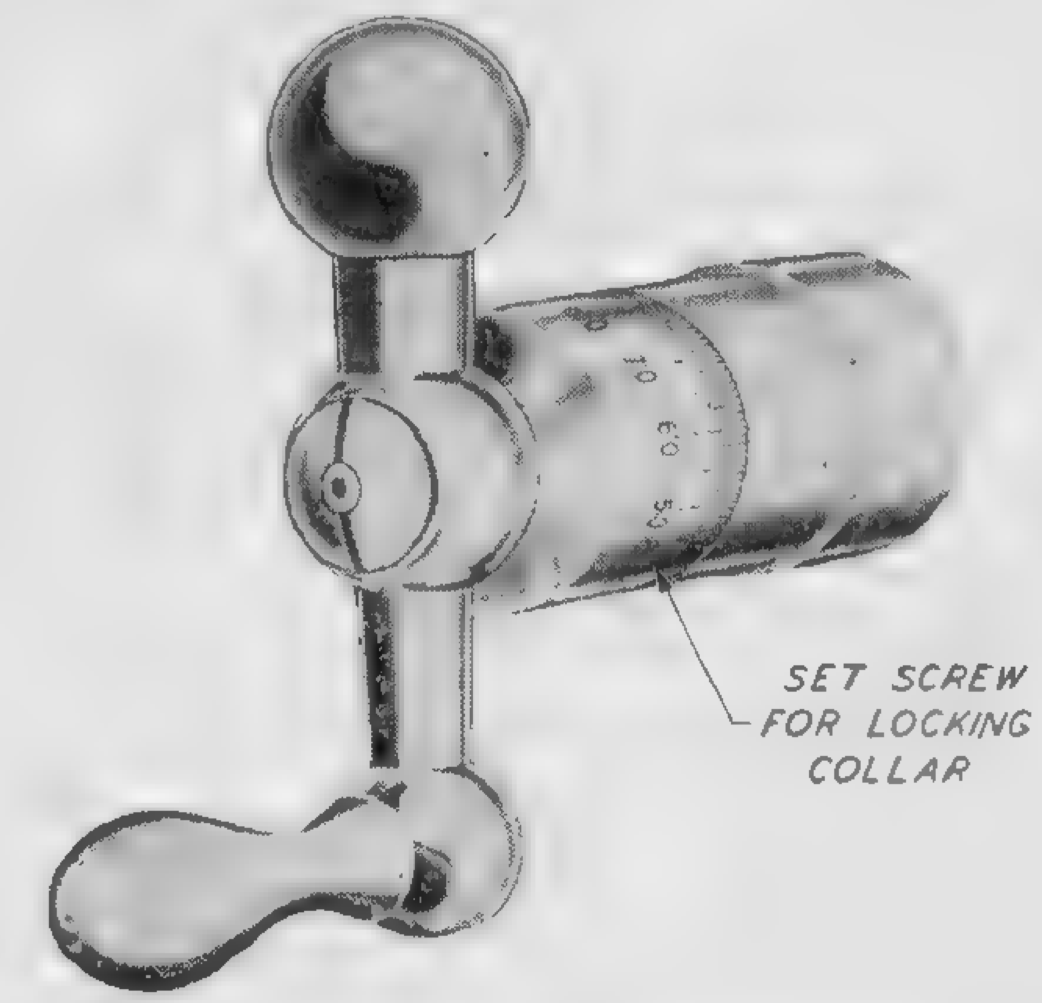



**Fig. 5. Micrometer Dial on Cross-Feed Screw of Lathe**
*Courtesy of South Bend Lathe Works, South Bend, Ind.*

screw is moved into the work one space or one thousandth that it is going to cut two thousandths from the diameter of the work. This is so because the work is turned continuously and metal is cut from both sides. To back up the cutting tool, it is necessary to screw it back far enough to take up the lost motion in the screw before the tool will start moving.

**LATHE DOGS.** As the frictional contact of the work on the live center is not sufficient to drive it, some device must be used to make the work rotate with the center. A lathe dog is used to accomplish this. For round work, such as a shaft, a dog like that shown in Fig. 6 is often used. The shaft or piece to be turned is placed in the hole, and held firmly in place by the set screw. The tail-piece is put through a hole in the faceplate, and the work rotates with the live center.

Although this type of dog is satisfactory in most cases, the contact between the dog and the faceplate being beyond the end of the piece, introduces a bending strain which is appreciable in slender work. To avoid this bending strain, lathe dogs are made with a straight tail, and they are driven by a stud projecting from the faceplate.

Fig. 6. Bent Tail Dog

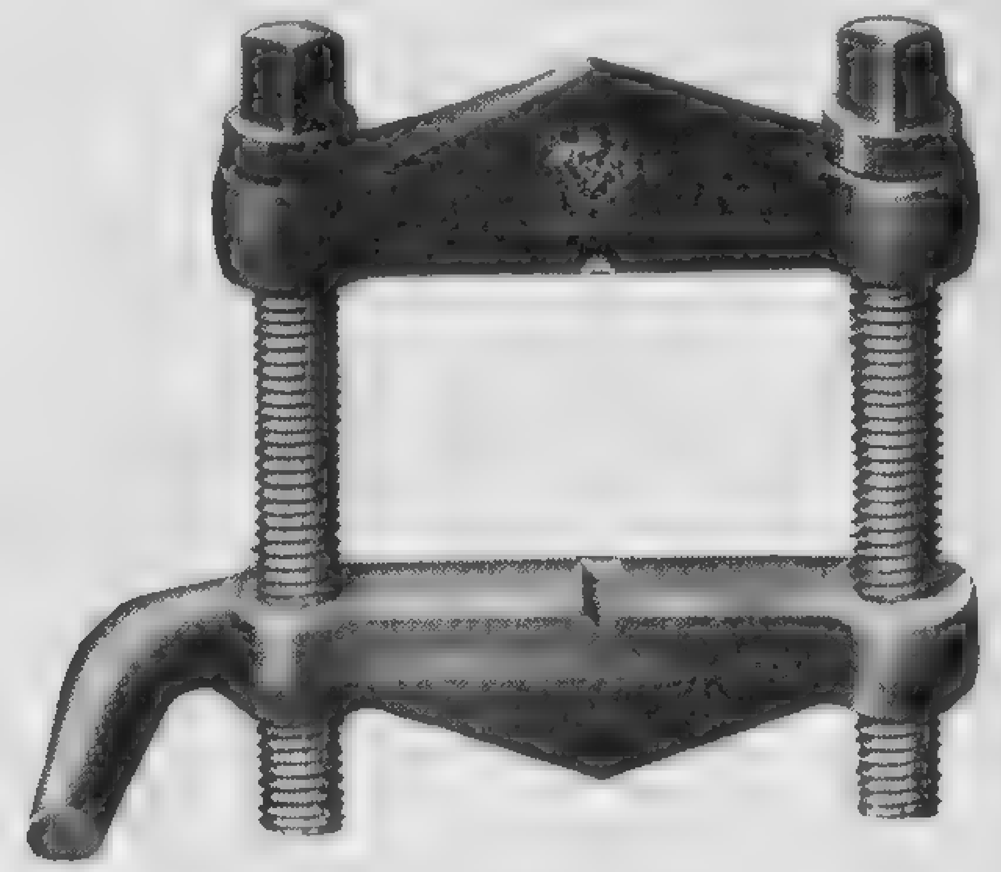


Fig. 7. Clamp Dog

*Courtesy of Armstrong Bros. Tool Co., Chicago*

For work other than round, a dog similar to the one shown in Fig. 7 may be used. The work is placed between the jaws, and held by the bolts.

Lathe dogs come in various sizes to accommodate large or small work.

**HOW TO USE THE LATHE DOG.** Figs. 8 and 9 show the correct and incorrect ways to mount a lathe dog. Notice the piece of material between the dog and the work to protect the finished surface.

### QUESTIONS AND ANSWERS

*1. What is the most commonly used machine in a machine shop?*

Answer. The lathe.

*2. What is the first thing the operator of a lathe does before starting off?*

Answer. Inspects and oils the machine.

*3. How is the size of a lathe determined?*

Answer. It is the maximum diameter that can be rotated over the ways of the bed; manufacturers do not state the maximum swing. For instance a 12-inch lathe may actually swing 12½ inches.

*4. Should the operator of a lathe have his sleeves rolled up?*

Answer. Yes.





### QUESTIONS

1. *What is the difference between a cone-head and a geared-head lathe?*
2. *What is the lathe apron?*
3. *What is the half-nut?*
4. *What is the headstock?*

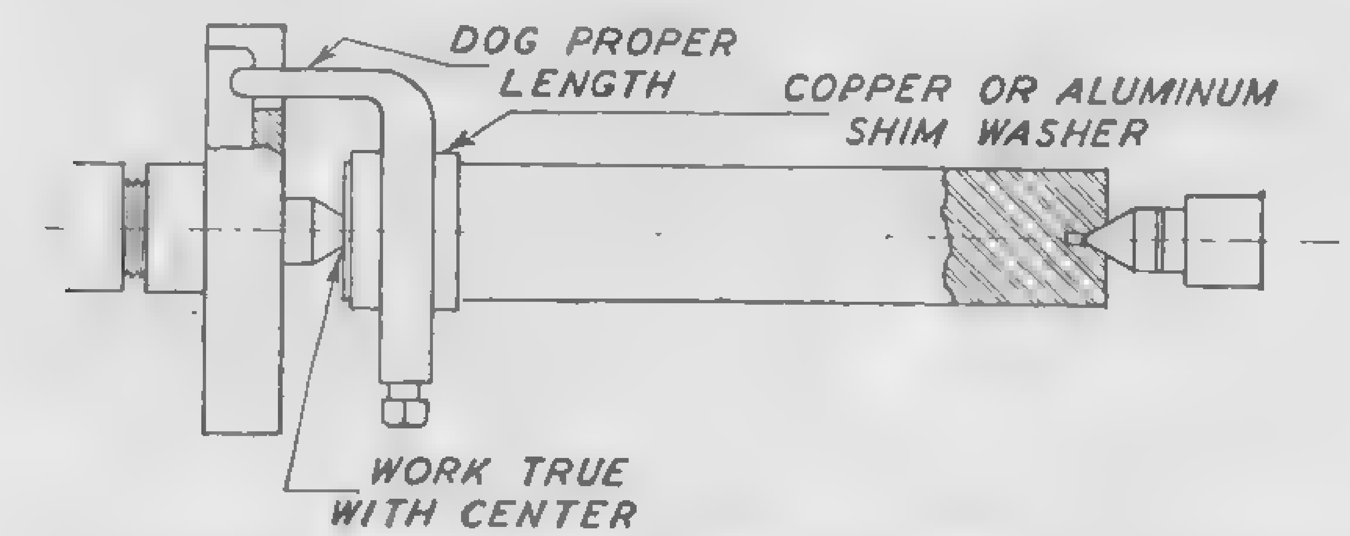



Fig. 8. Work Properly Mounted Between Centers with Lathe Dog Properly Used

5. *For what is the lead screw used?*
6. *Explain the principle of the back-gear action.*
7. *Is the locking pin used when the back gears are meshed?*
8. *What is the purpose of having several spindle speeds?*

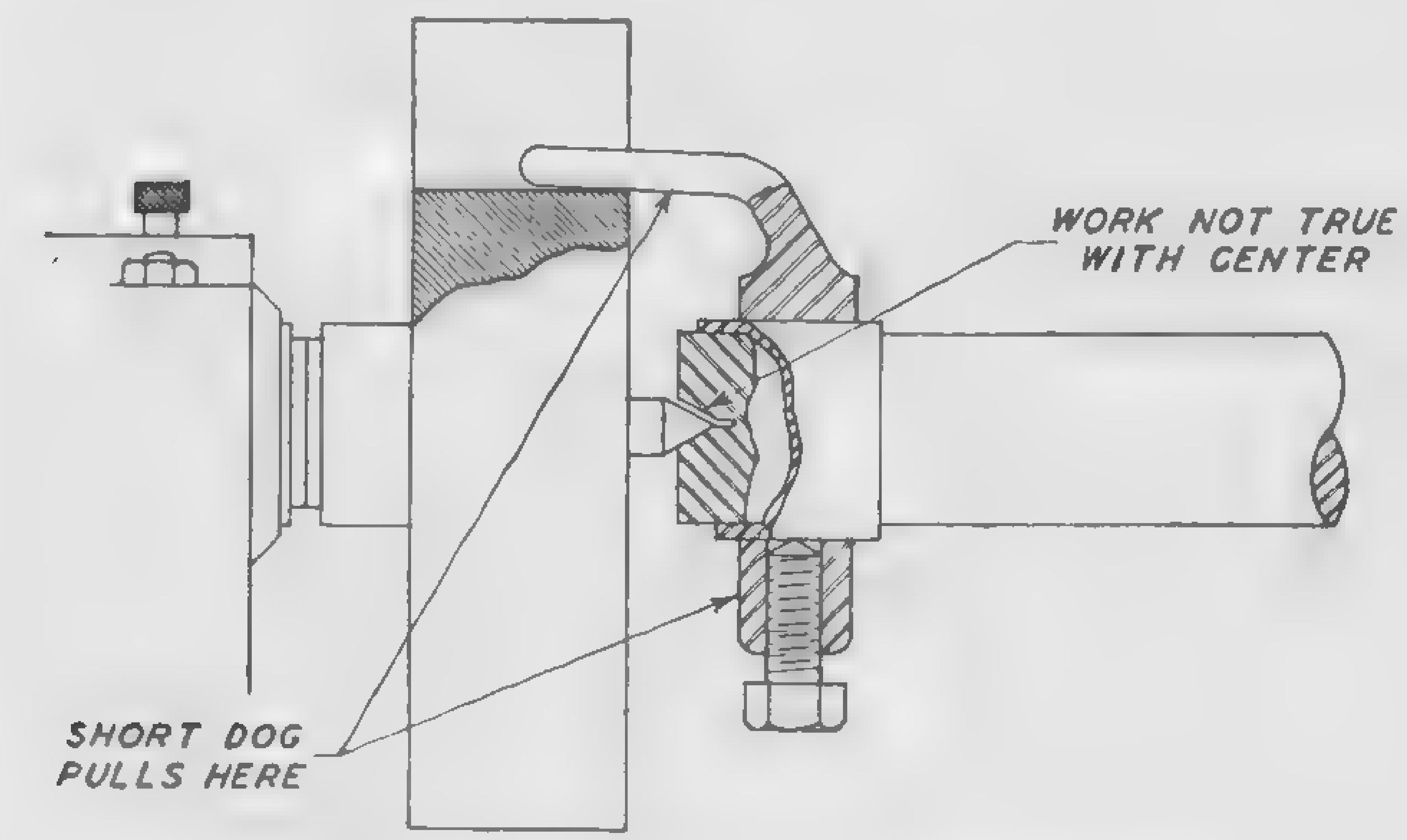



Fig. 9. Work Incorrectly Mounted Between Centers

9. *Name the principal parts of the engine lathe.*
10. *How many speed changes will a lathe with a 4-step pulley have?*

### DRIVING THE WORK

1. *What are the common types of lathe dogs?*
2. *Should the work be mounted before tightening the lathe dog, or vice versa?*
3. *Why is it important that a lathe dog of proper size be used?*
4. *How should work be protected from damage by lathe dog screws?*

## TURNING TOOLS

**GENERAL CHARACTERISTICS.** The cutting tools used in lathes present a great variety of shapes. These shapes are adapted to the work that is to be done, and to the kind of finish that is to be left upon the metal. There are two fundamental requirements for all

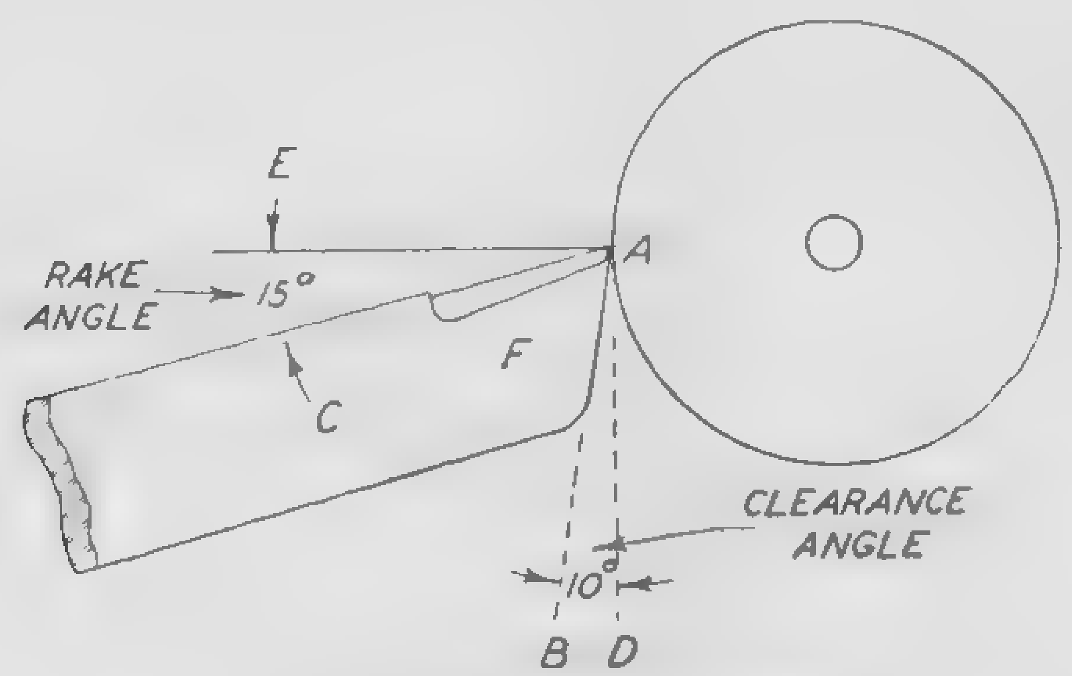



Fig. 10. Cutting Tool Angles

cutting tools: (1) The cutting edge alone must touch the metal; and (2) the edge must be keen.

A typical tool is shown in Fig. 10. The cutting edge of the tool at $A$ is in contact with the work. The bottom line $AB$ runs back from the metal and does not touch it. The top face $F$ slopes down. The line $AD$ is a tangent at the cutting point, and the line $AE$ is

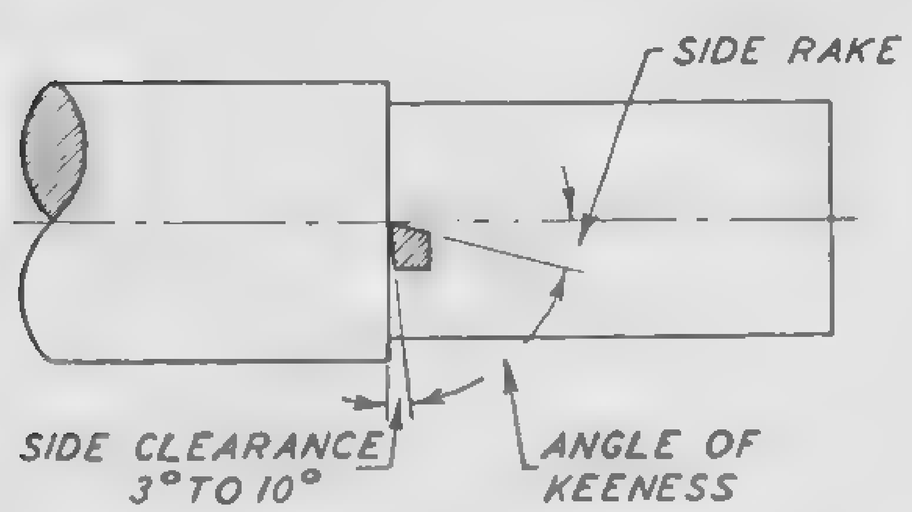



Fig. 11. Correct Side Clearance and Cutter Rake

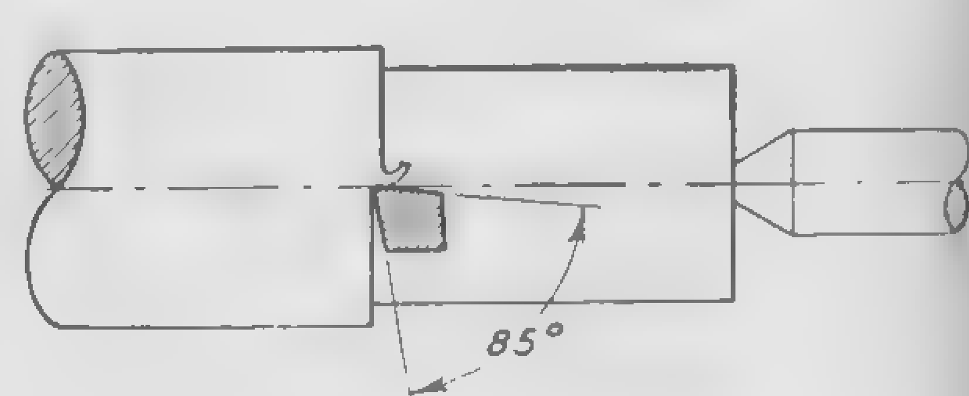



Fig. 12. Tool Angle for Machining Very Hard Cast Iron

radial at the same point. Therefore, the angle $DAE$ is always a right angle. The angle $DAB$ is called the *angle of clearance* and should be small—not over 10 degrees. This angle is shown also in Fig. 11. The angle $CAE$ is called the *angle of rake* and should be as great as circumstances will permit, about 15 degrees on lathe tools for wrought





iron and steel, leaving 75 degrees for the solid angle or the cutting angle.

**TEXTURE OF WORK DETERMINES TOOL ANGLE.** The physical qualities of the material to be turned will to a great extent determine the cutting angles of the tool: (1) Whether it is hard or soft; and (2) whether it is brittle or tough.

The degree of hardness of a material determines how much can be removed in a given time; that is, whether the speed of cutting

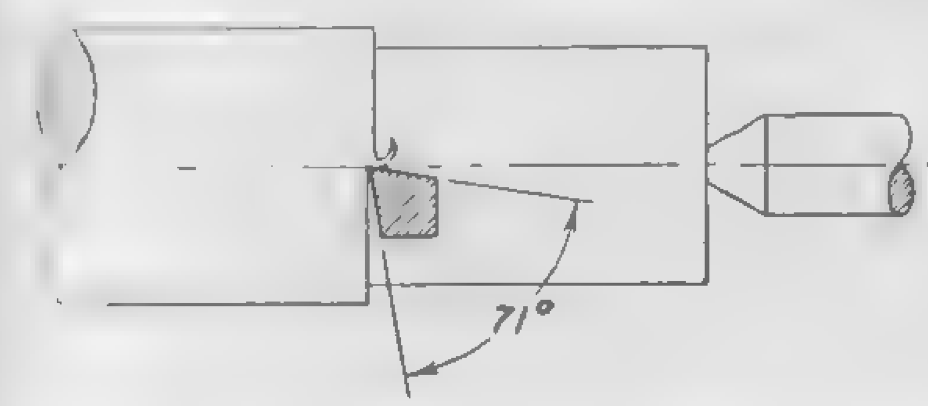



Fig. 13. Tool Angle for Machining Cast Iron

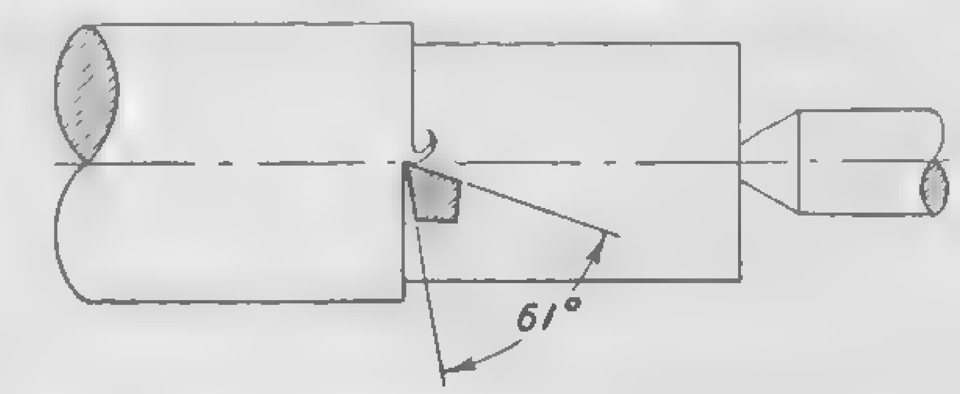



Fig. 14. Tool Angles for Machining Soft Steel

shall be fast or slow, and whether the feed shall be coarse or fine. A brittle or tough nature will make considerable difference in the top angles of the tools. This will be seen readily in the tendency of a brittle metal (as cast iron) to break up into small chips, while the tough metal turnings will curl off into spiral or helical shavings. Therefore, the tough materials will require tools of sharper angles than those for a brittle metal.

For cutting soft brass and similar metals, the top surface $AC$ of the tool will be practically level, while the face angle $DAB$ will be 3 degrees or frequently less.

Figs. 12, 13, and 14 illustrate tool angles for machining different materials.

**CLEARANCE.** Clearance prevents the tool from rubbing on the work, while rake adds to the keenness of the cutting edge, and gives freedom to the removal of the chips.

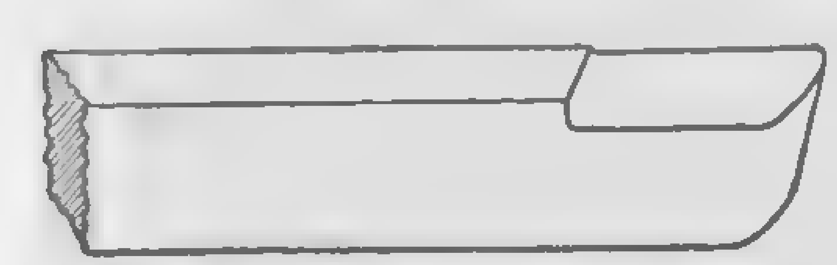


Fig. 15. Right-Hand Turning Tool

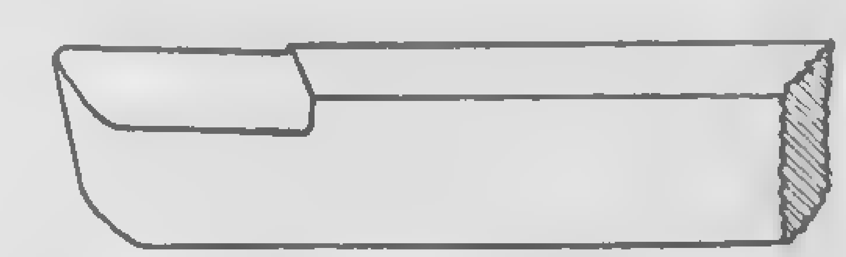


Fig. 16. Left-Hand Turning Tool

**COMMON FORMS OF TURNING TOOLS.** The common forms used are the right-hand and left-hand turning tools illustrated in Figs. 15 and 16, right-hand and left-hand side or facing tools illustrated in Figs. 17 and 18, and the square-nose tool used in finishing

the periphery of large shafts, pulleys, etc., where the surface is large enough to justify its use. The square nose tool is ground straight across the face and stoned with an oil stone so that the face is slightly convex, as shown in Fig. 19. A very light cut is taken and as the feed is less than the width of the tool, the overlap of the tool in the cut causes a slight scraping action, leaving a smooth finish. A flood of coolant should be used when finishing steel, but cast iron should

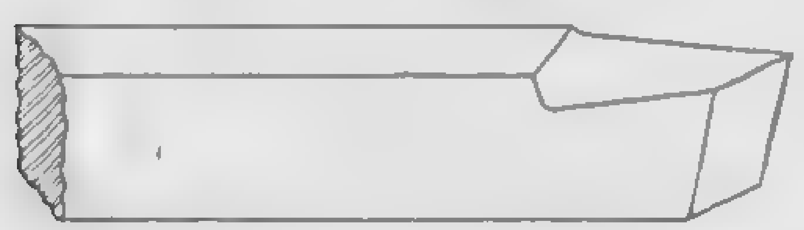


Fig. 17. Right-Hand Side or Facing Tool

Fig. 18. Left-Hand Side or Facing Tool

be finished dry, as any moisture on the surface when taking a light finishing cut on cast iron will glaze and the next advance of the feed will cause the tool to "crowd" away from the cut.

**Side or Facing Tools.** In the past it was the custom to use forged tools of carbon tool steel. With the advent of high-speed steels the forging was eliminated, due to waste in forging and the cost of forging. The tools are shaped by grinding. This serves a double purpose—it saves the cost of forging and the tools are practically the full size of the steel, which serves to conduct away the heat generated in cutting the material being machined.

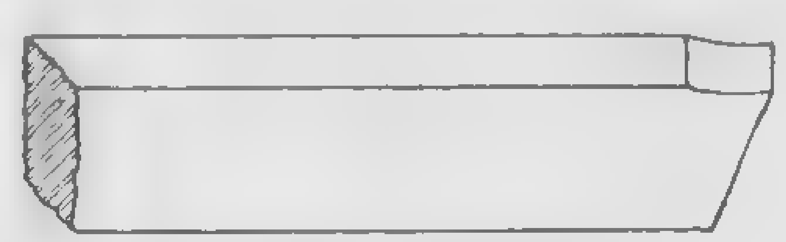


Fig. 19. Finish Turning Tool (Square Nose)

**Cutting-Off or Parting Tool.** This tool is illustrated in Fig. 20. The blade is quite narrow—as narrow, in fact, as the character of the work will allow. As the blade needs to be narrower at the shank and at the bottom than it is at the cutting edge, it follows that the tool will be weak. It must be set horizontally, so that, as the tool is fed to the work, only the cutting edge will touch the metal. It must also be set so that the cutting edge will pass through the axis of the work as it is fed to the center. If set too high, it will cease to cut before the center of the work is reached; while if too low, the tool has a poor scraping action, and will leave a portion of the work





uncut. On work held between centers, one should not attempt to cut to the center of the piece, as the work will surely ride up onto the tool.

**BORING TOOLS.** The term *boring* as used in machine practice usually means methods of machining internal surfaces, other than those of common drilling and reaming. Also methods for holding the work other than those common to ordinary drilling and chucking operations are often used. When boring machine parts, use may be made of the common inside turning tools or of special appliances termed *boring bars.*

When a hole is to be bored in lathe work, tools of a shape different from those used in turning should be employed. The general form

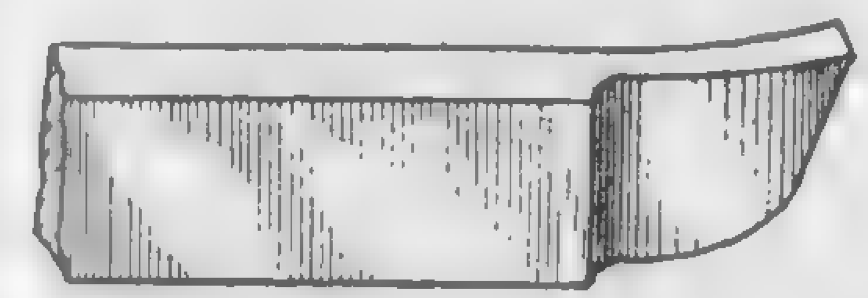


Fig. 20. Cutting Off or Parting Tool

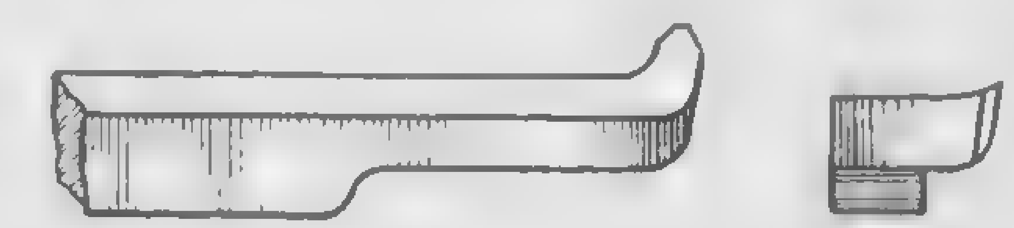


Fig. 21. General Form of Boring Tool

of the tool when forged is shown in Fig. 21. Length of shank depends on depth of the hole to be bored, for it must be long enough to reach from the tool-post to the bottom of the hole. This overhang makes the tool more likely to spring, and necessitates a much lighter cut being taken than when removing the same amount of metal by outside turning tools. The result of this lighter cut is seen in the increase of time required to remove a given amount of stock. The shape of the cutting edge is practically the same as that of the tools for turning, except that the boring tool must have more clearance to avoid striking the work. Therefore, with the same solid angle, the tool will have less rake. The reason for this will be seen by comparing Figs. 10 and 22. In Fig. 10, it will be seen that the surface of the work is outside a tangent at the cutting point and can never interfere with the bottom of the tool. In Fig. 22, the surface of the work is inside the tangent, and, unless the tool has a large amount of clearance, it will cause trouble by striking the concave surface.

**TOOLS FOR BRASS.** Tools for brass differ from those used on steel and iron in that they have no rake. A tool suited for working brass is shown in Fig. 23. Brass does not readily split, and the chips break off as soon as started from the main body. When turning steel,

the metal does not break as readily and may form long spiral chips if the tool is in condition. If a tool with top rake is used in turning brass, the work will not only be rough in appearance, but there is great danger of the tool gouging into the stock and spoiling the work or tool, possibly both. The finishing tools for brass may be square or round-nosed, without rake; in fact, a small amount of negative rake will produce a much better surface. When the brass contains a large percentage of copper, some rake to the tool may be required, owing to the ductility and toughness of the metal.

The tools which have been mentioned are forged to approximately the correct shape, then ground on a tool grinder. These

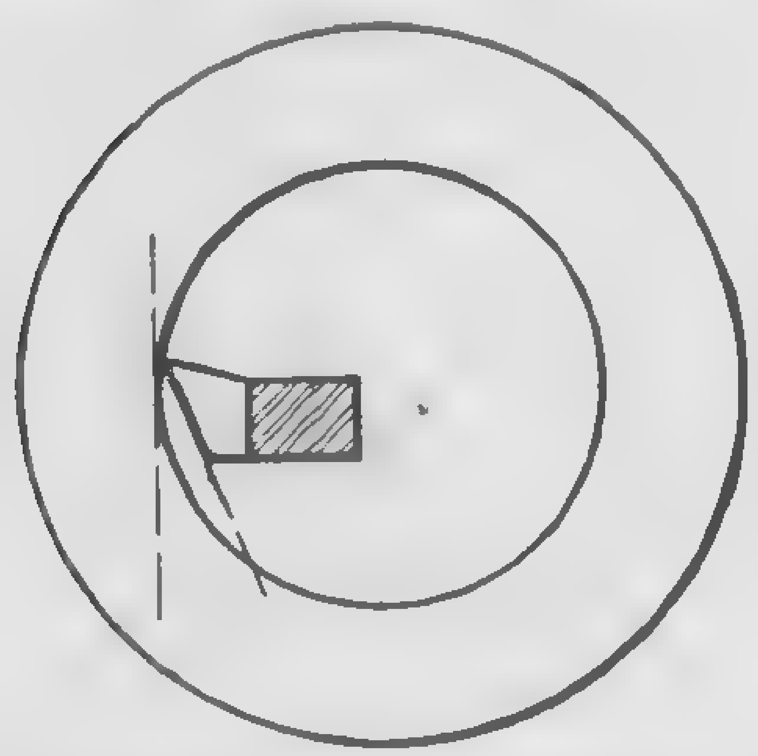


Fig. 22. Boring Tool Set for Clearance

Fig. 23. Tool for Turning in Brass

tools have a good advantage over small tools for heavy work, as they serve to conduct away the heat generated when cutting material. Forged tools are expensive, since they are so much larger than the small cutter bits used in tool holders.

Fig. 24 shows a complete set of lathe tools and holders. The shape of the tool has an important influence on the amount of work it can be made to do. As has already been explained, these shapes vary with the different metals that are being worked, and also with the class of work performed. It is highly important that the cutting angles be correctly formed. While hand-grinding on the emery wheel is fairly satisfactory, the best results can be obtained by the use of a regular tool-grinding machine, as shown in Fig. 25. In addition to the grinding, tools for fine finishing should be whetted carefully on a fine oil stone.

**CARBIDE TOOLS.** Tools with tips of tungsten and tantalum carbide have become very popular where economy of manufacture





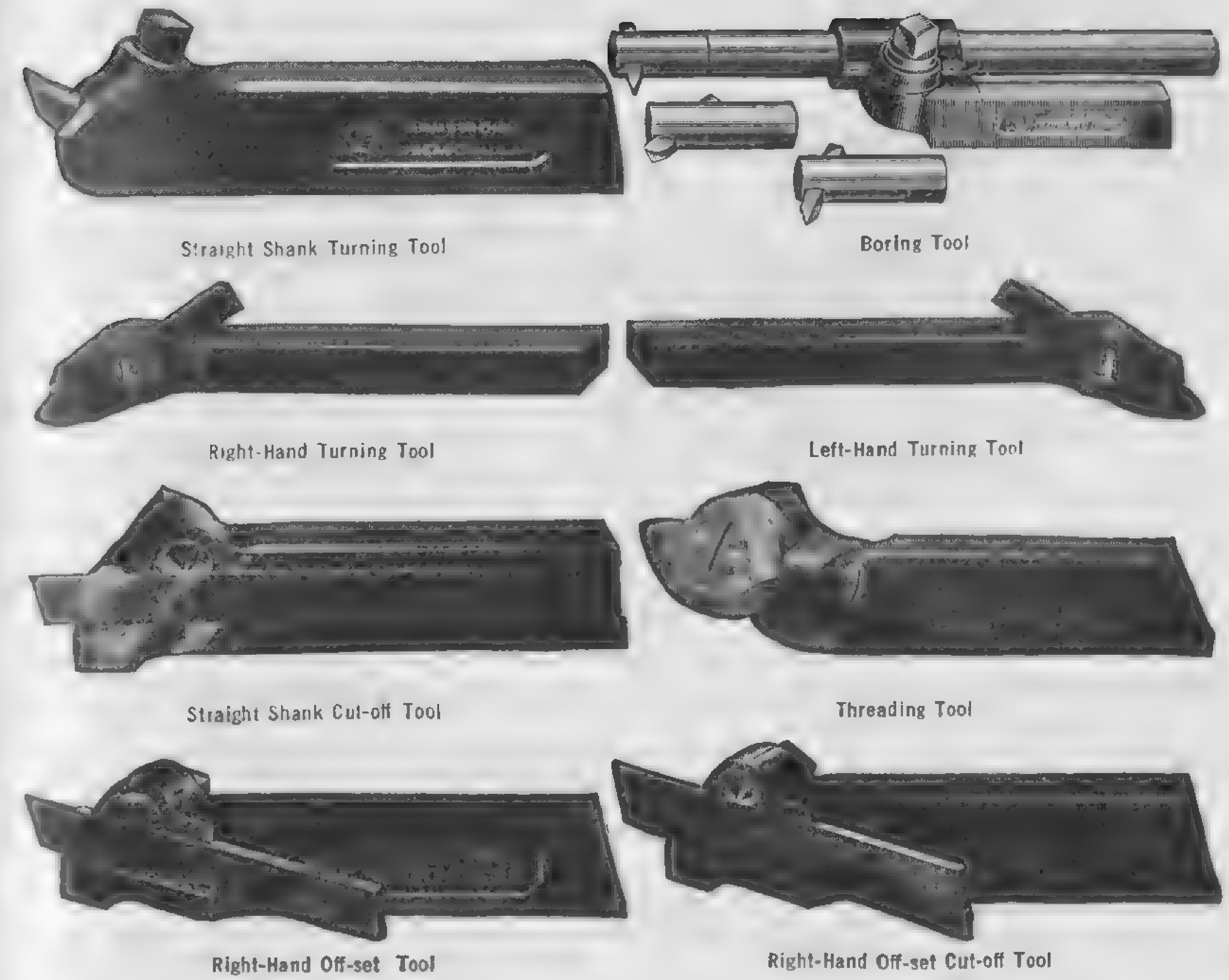



Fig. 24. Set of Lathe Tools and Holders
*Courtesy of Armstrong Bros. Tool Co., Chicago*

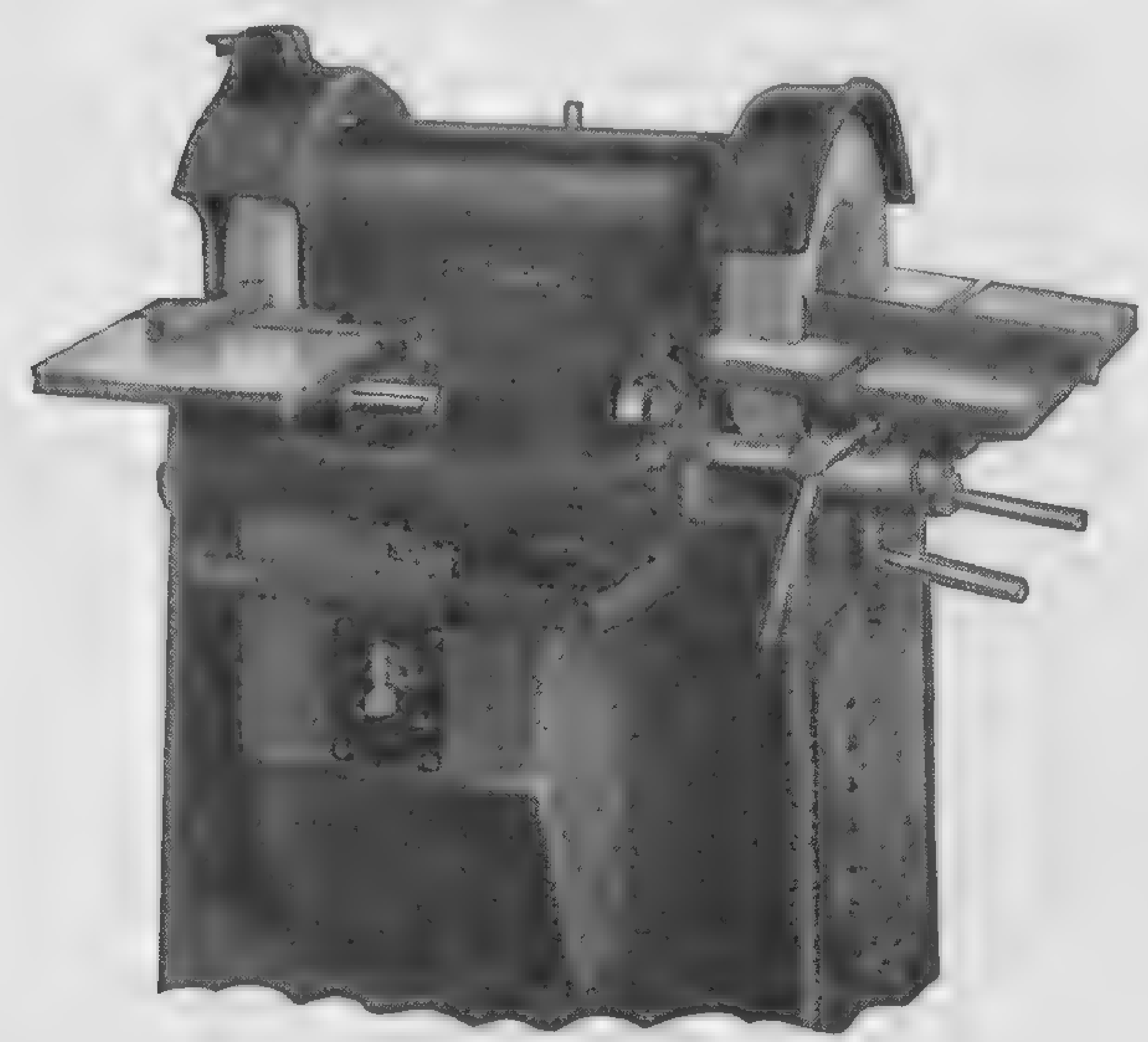


Fig. 25. Tool Grinding Machine
*Courtesy of Carboloy Company, Inc., Detroit, Mich.*


Fig. 26. Carbide Tools in Typical Shapes
*Courtesy of Carboloy Company, Inc., Detroit, Mich.*





has justified their use. The tools are the same general shape. The advantage is that very much higher cutting speeds can be used. In hardness the tungsten carbide ranks next to diamond. Fig. 26 shows a few of the shapes used.

### GENERAL DIRECTIONS FOR GRINDING THE TOOL

1. Wear your goggles.
2. Use a coarse grinding wheel to grind away most of the metal, then finish with a fine wheel.
3. Hold the tool on the periphery of the wheel.
4. Do not use too small a wheel. If the wheel is too small, it will undercut the cutting edge, and the tool will not have the correct angle.
5. Do not overheat the tool.
6. Hold the tool in such a way that the wheel marks are in the same direction as the material will be when turning in the lathe.
7. When the tool is taken away from the wheel for inspection or cooling, it should be replaced at the correct angle.
8. Move the tool back and forth on the wheel. Holding it in one place will wear a groove in the wheel.
9. Support the hand not the tool on the tool rest.

### STEPS IN GRINDING THE LATHE TURNING TOOL

**Step 1.** Hold the left side of the tool at the correct angle to form the side clearance, as shown in Fig. 27.

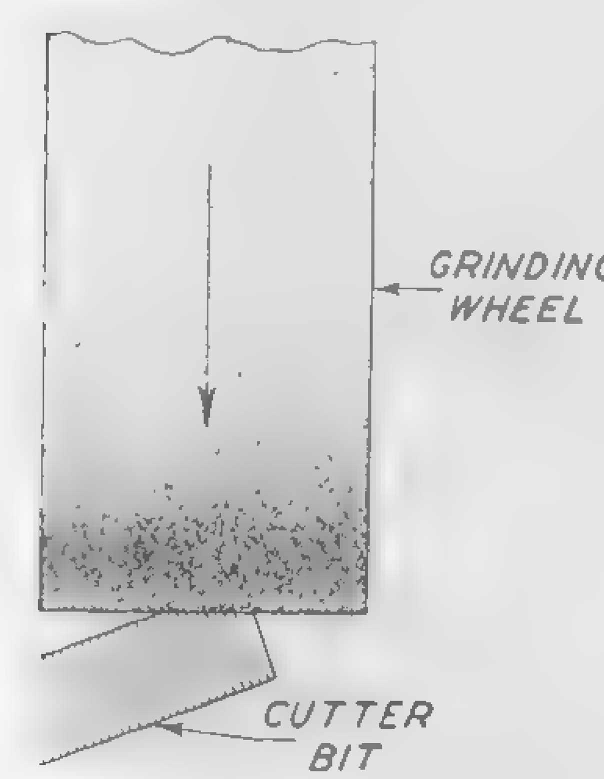



Fig. 27. Step 1—Grinding the Lathe Tool for Side Clearance

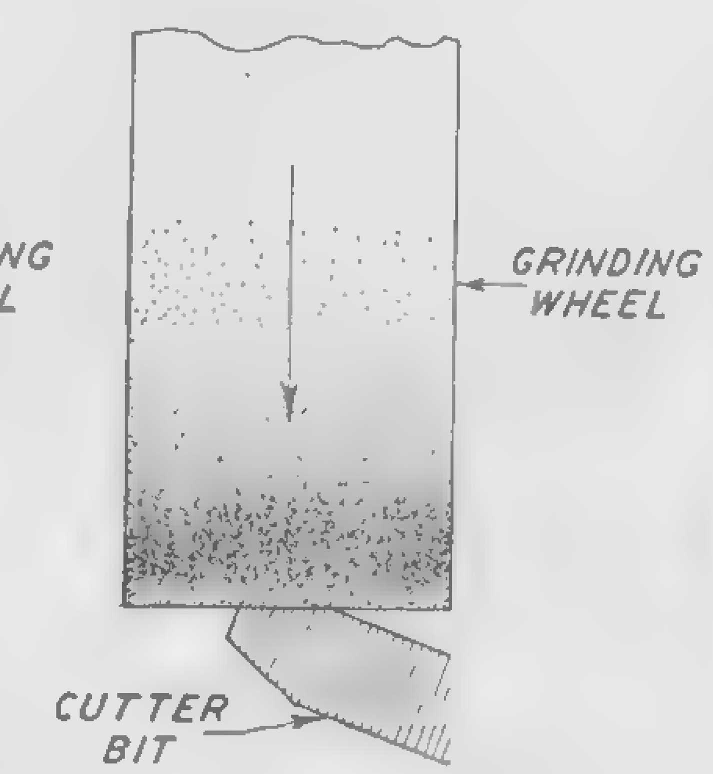



Fig. 28. Step 2—Grinding the Right Side for Clearance

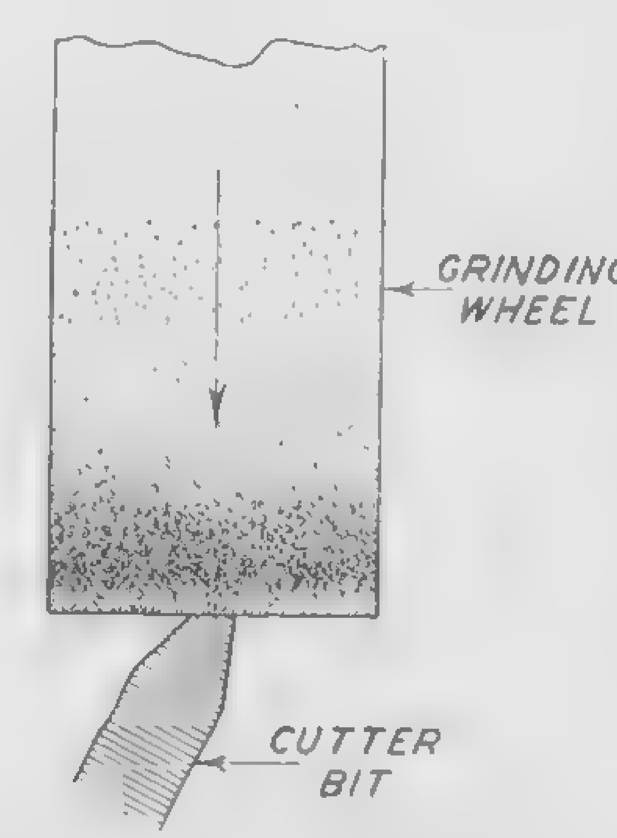



Fig. 29. Step 3—Grinding the Lathe Tool for Radius

**Step 2.** Grind the right side of the tool, holding it in the correct position, Fig. 28, until it is nearly at a point. This will depend on the radius it is to have on the point.

**Step 3.** Grind the radius on the point, Fig. 29. When in use a small radius will not chatter so quickly as a large one. Hold the tool and turn it from side to side to produce the required radius.

**Step 4.** Hold the tool at the correct angle to make the proper front clearance, Fig. 30.

**Step 5.** Grind the top of the cutter bit, Fig. 31, holding it at the proper angle to get top rake. It should be held in such a position that the wheel marks will be in the same direction as that of a chip being cut from the material.

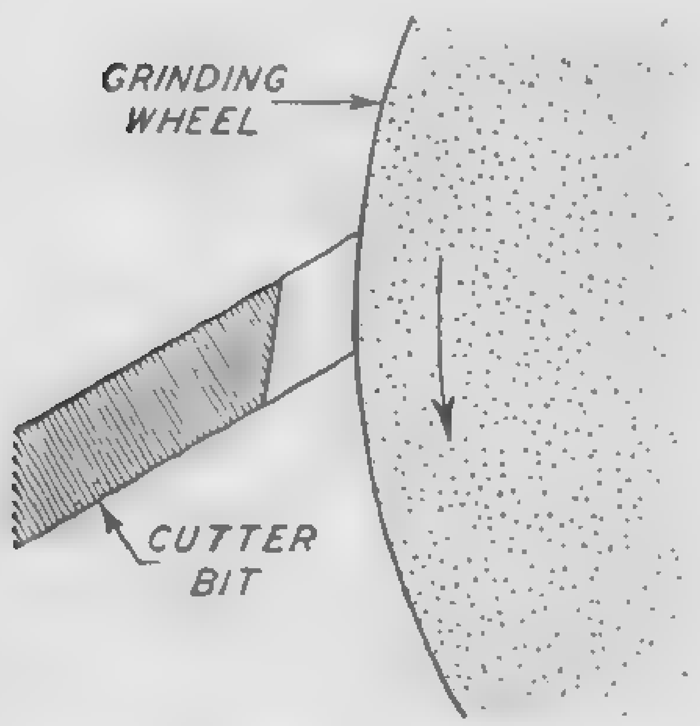



Fig. 30. Step 4—Grinding the Lathe Tool for Front Clearance

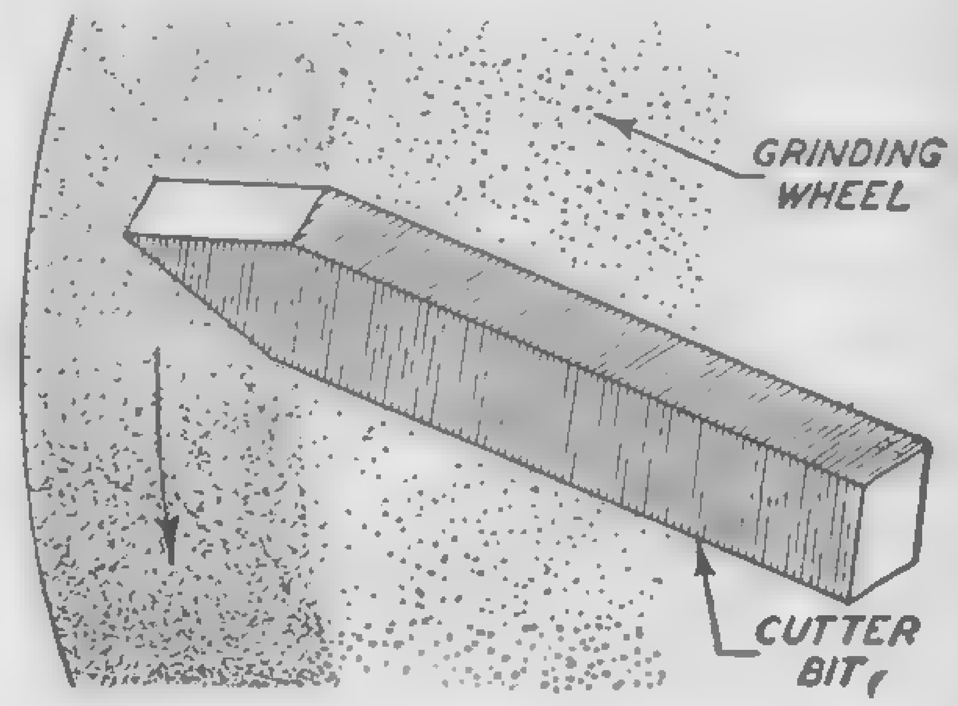



Fig. 31. Step 5—Grinding the Lathe Tool for Top Rake

## HOW TO GRIND A CUTTER BIT TO FIT A CENTER GAGE

1. Grind the left side of the tool to 30°.
2. Grind the right side to 30°. This will make a 60° included angle.
3. Place the tool in the center gage, Fig. 32, in the proper angle. Hold the tool to the light. If the tool is ground perfectly, light will not show through between the gage and the tool.

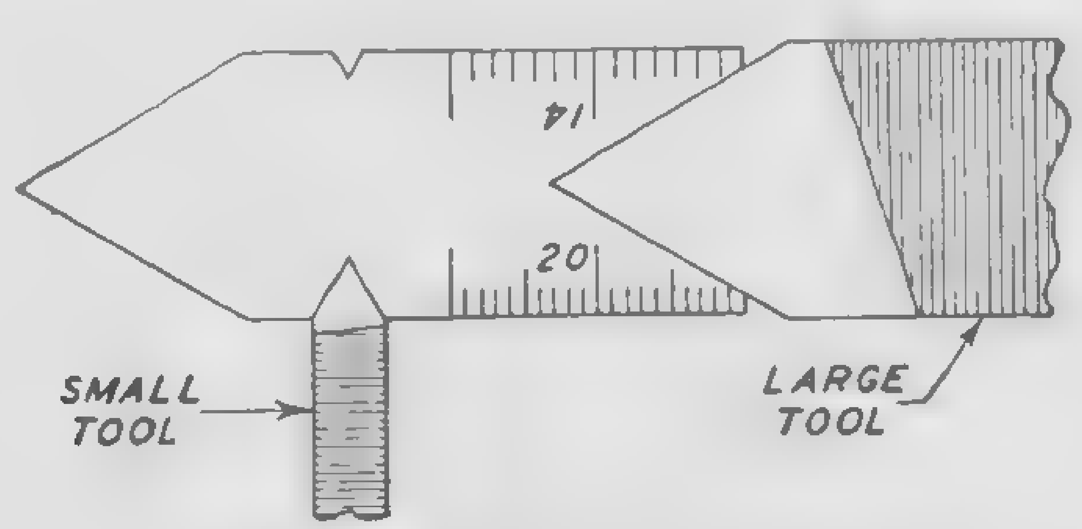



Fig. 32. Tools Ground to Fit Center Gage

## APPLICATIONS OF LATHE TOOLS

The illustrations in Fig. 33 show the application of nine shapes of ground cutter bits commonly used for machining material in the lathe.





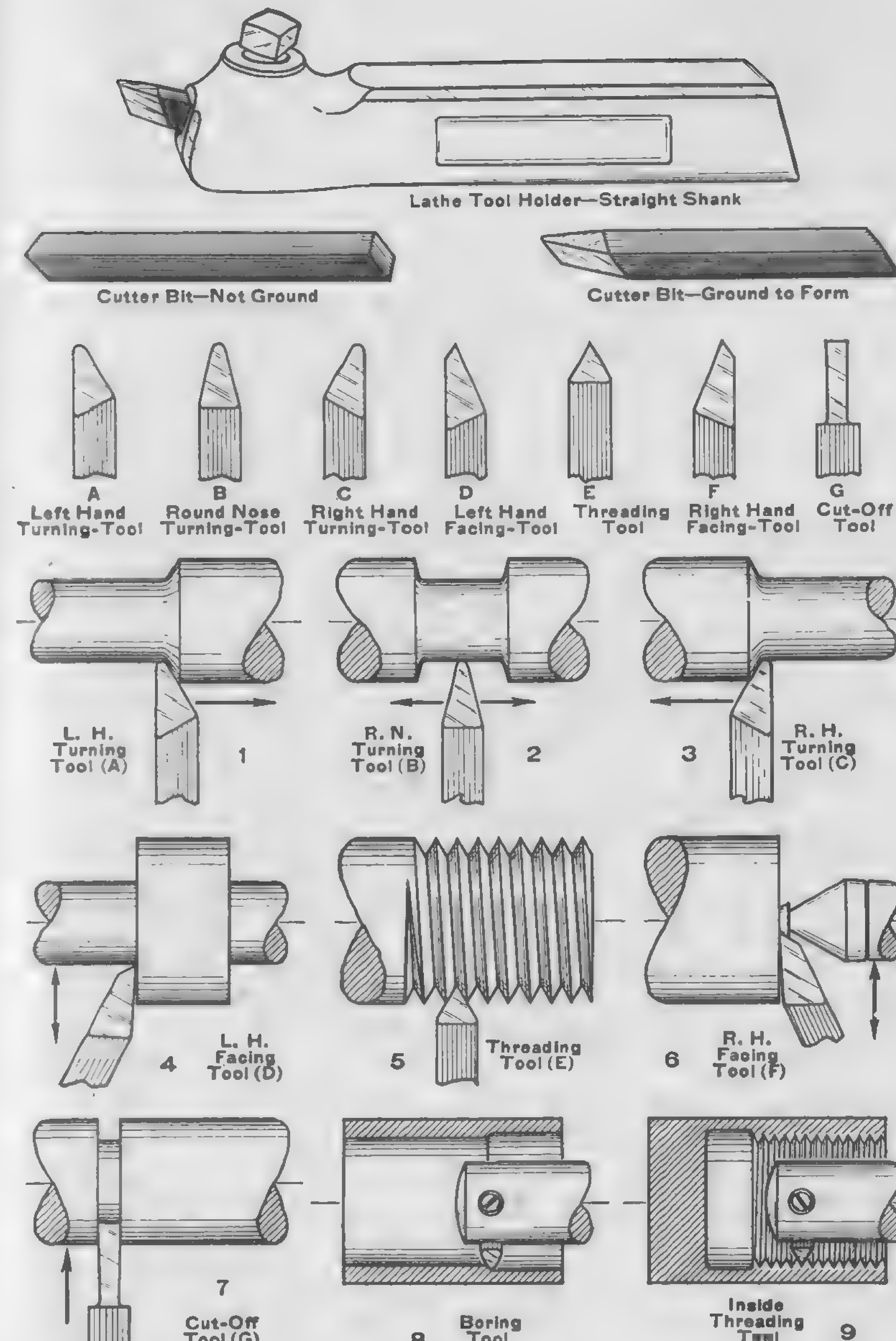
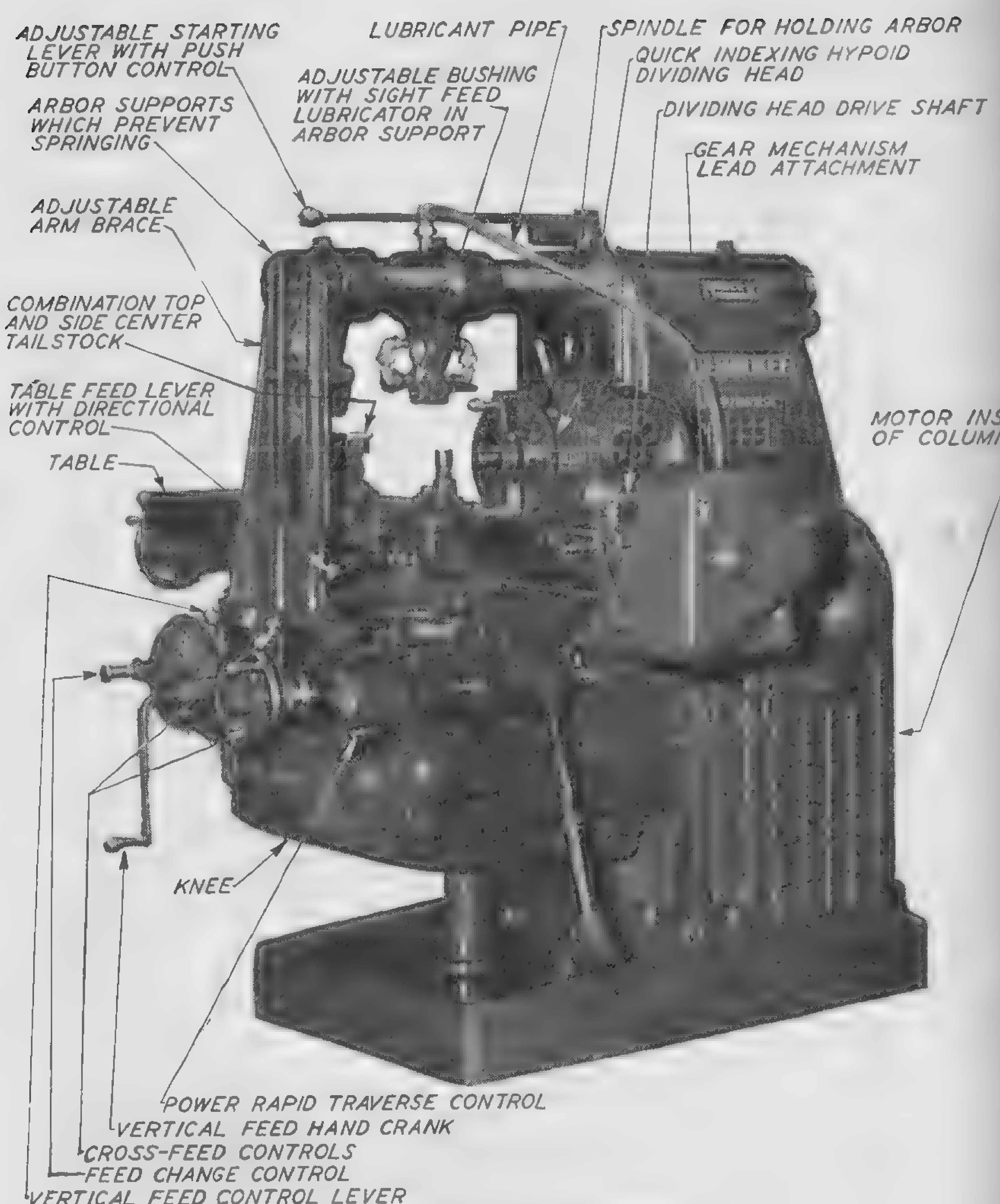



Fig. 33. Application of Lathe Tools
*Courtesy of South Bend Lathe Works*




UNIVERSAL MILLING MACHINE

*Courtesy of Kearney & Trecker Corp., Milwaukee, Wis.*



PART 2

# Airplane Construction

**Construction Details.** Under the pressure for time on commercial orders and the gigantic program of defense, aircraft manufacturing has developed production-line procedures similar to those extensively used in the automobile industry. No longer are planes single, tailor-made jobs. With orders coming through for 50, 100, and more of specified designs it is now possible to take advantage of production-line manufacturing. Therefore, we see the installation of jigs and fixtures of every description for the mass manufacturing of fuselages, wings, stabilizers, rudders, etc. See Fig. 1.

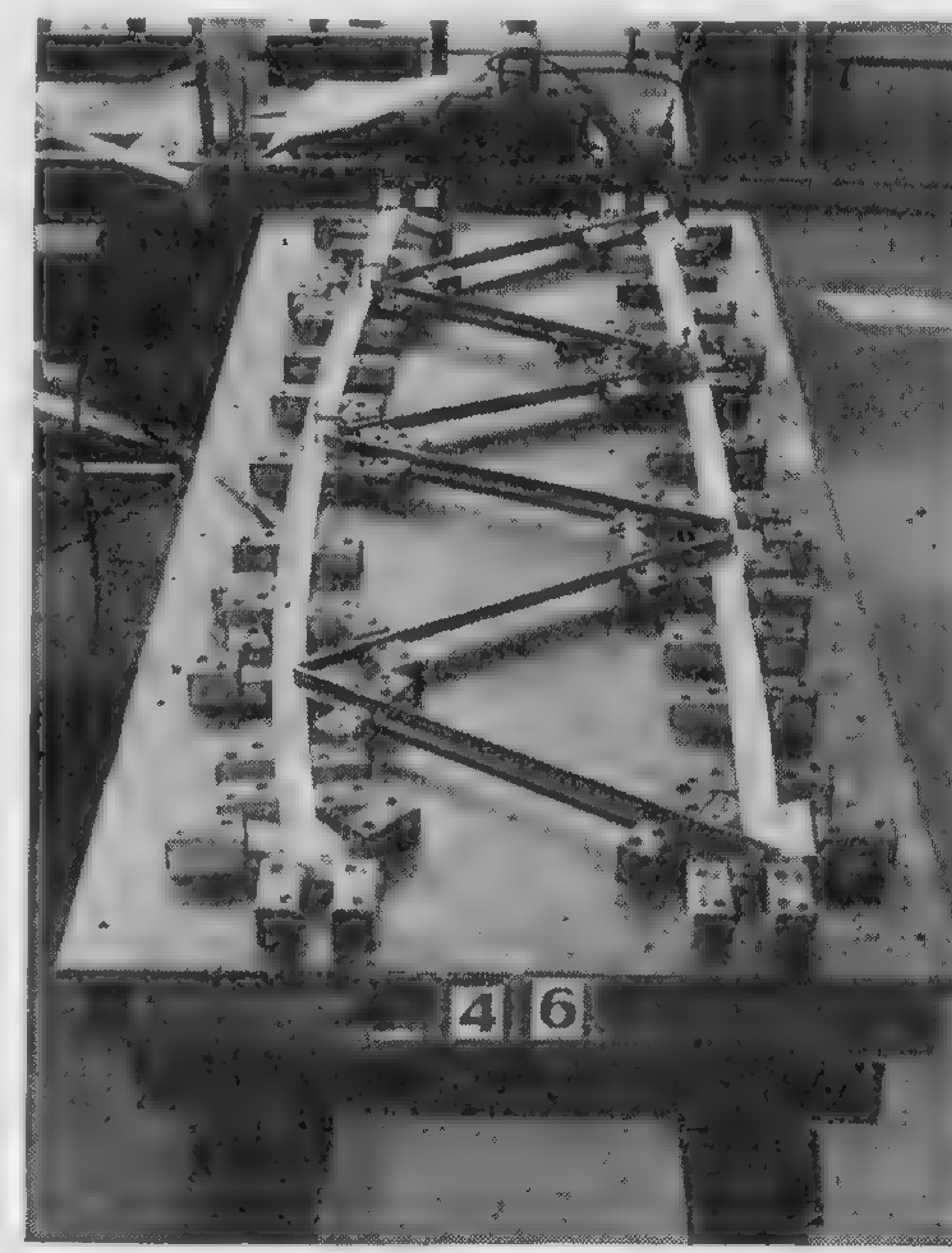
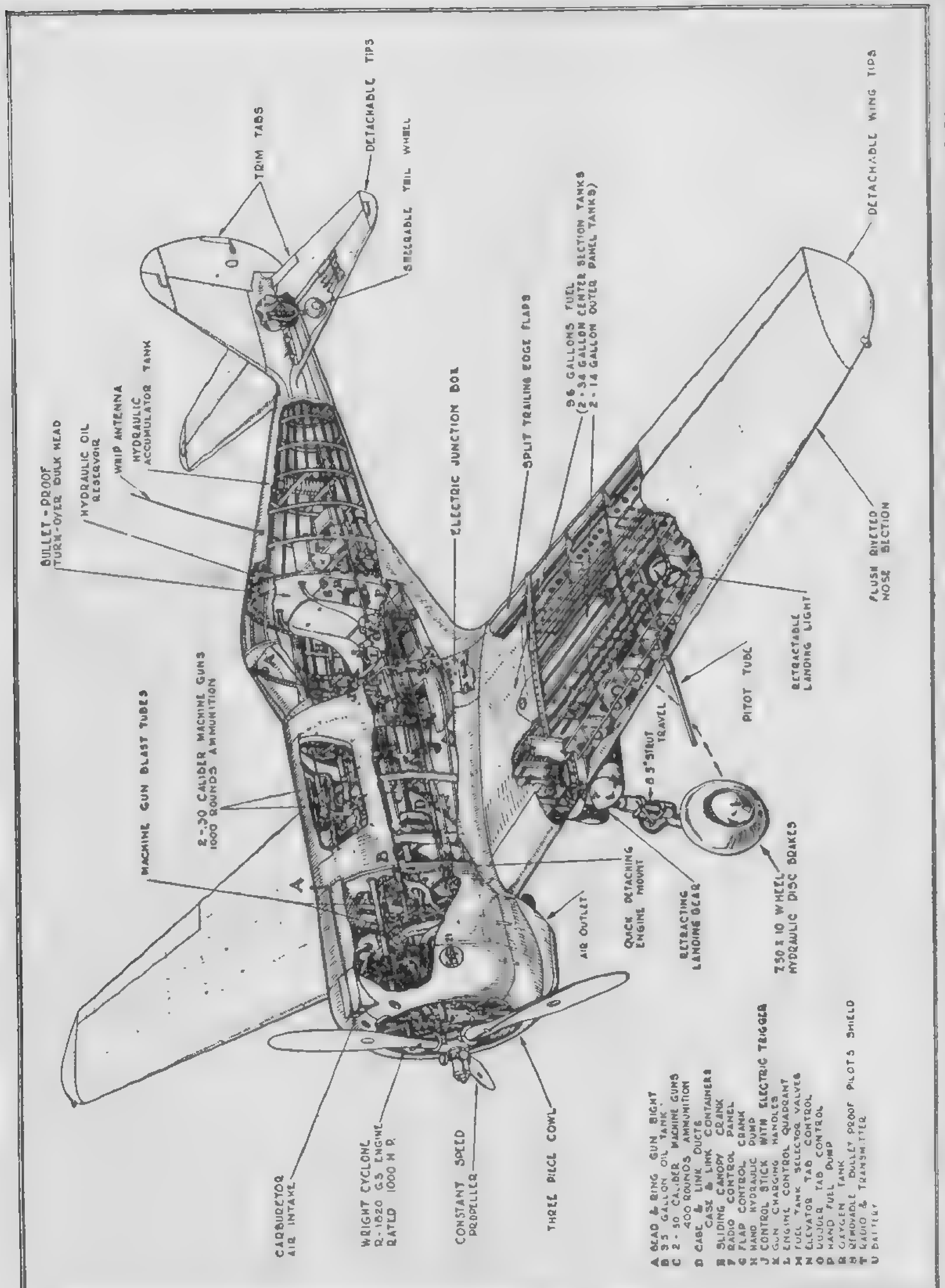



**Fig. 1. Wooden Assembly Board Used to Hold the Various Parts of a Minor Assembly in Place while the Drilling and Riveting Is Done. This Is a Central Portion of a Wing Rib**

*Courtesy of Consolidated Aircraft Corporation, San Diego, California*

In addition to these jigs, overhead trolleys carry parts; in some cases in the manufacture of smaller planes, fuselages, wings, and other main parts are moved from one section of the plant to another in the process of manu-

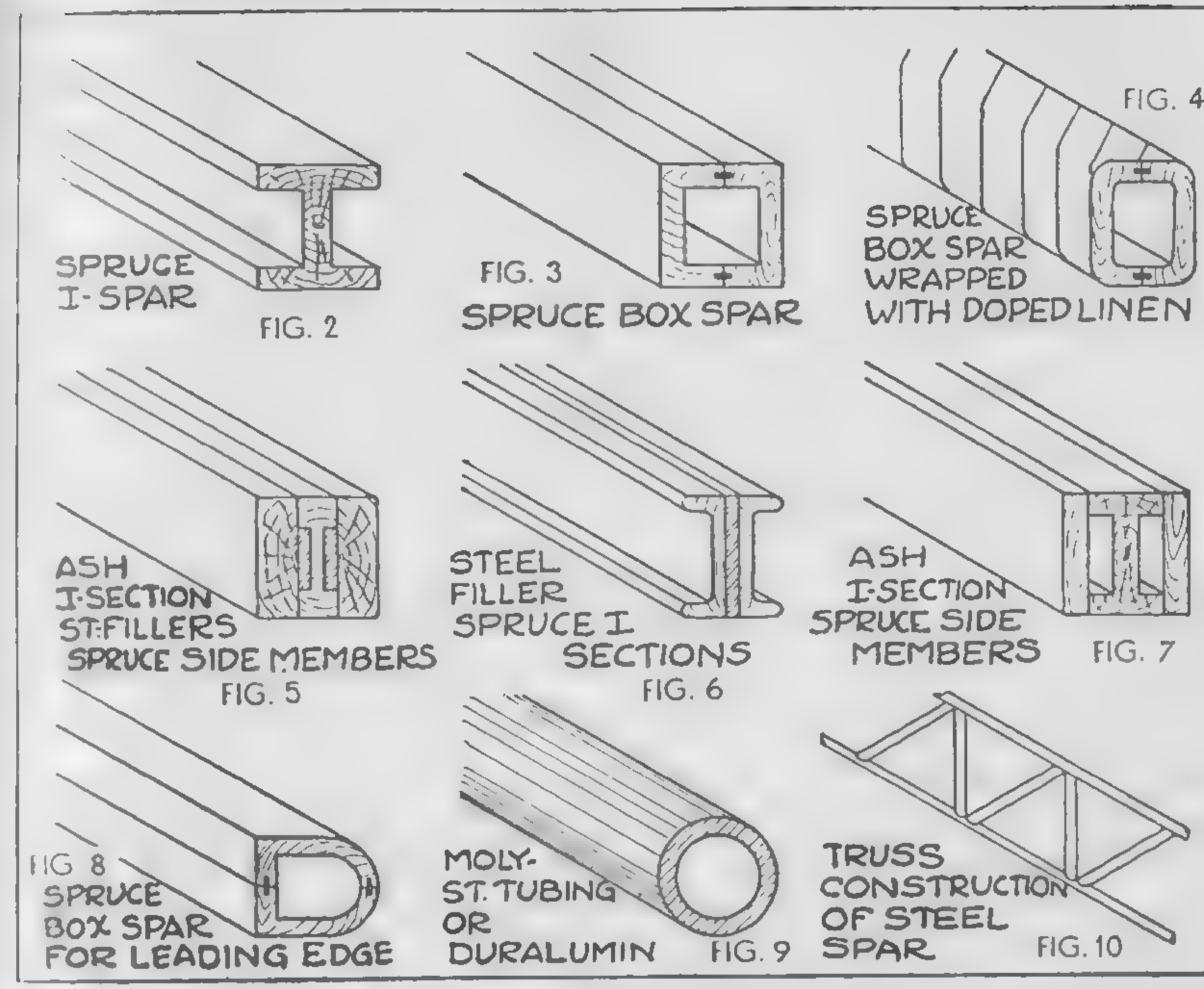


Cut-a-way View of Curtiss-Wright Interceptor Showing Details of Fuselage, Wings, and Other Parts of Plane

*Courtesy of Curtiss-Wright Corporation*








facturing. As each operation is completed, the job is shunted along to each succeeding section until the cockpit, brakes, control and wiring system, doping, sanding, and rubbing are entirely completed.

Every part of an airplane is subjected to stresses and strains, and obviously this is particularly true of the wings because the forces applied to a wing may increase or decrease quite suddenly.

A force that is applied suddenly is more destructive than a force that is applied steadily; therefore, the construction of an airplane wing must be such as to withstand sudden and varying applications of "lift".

In building a wing the first thing to determine is how much of a load the wing is to carry. After this has been done, the designer determines what type of spar should be used to carry the weight.

The first spar, Fig. 2, is called an **I** spar. This type is generally made from a solid piece of spruce which has been hollowed or routed out along the sides to reduce weight, because this shape makes a stronger section for a given amount of weight.

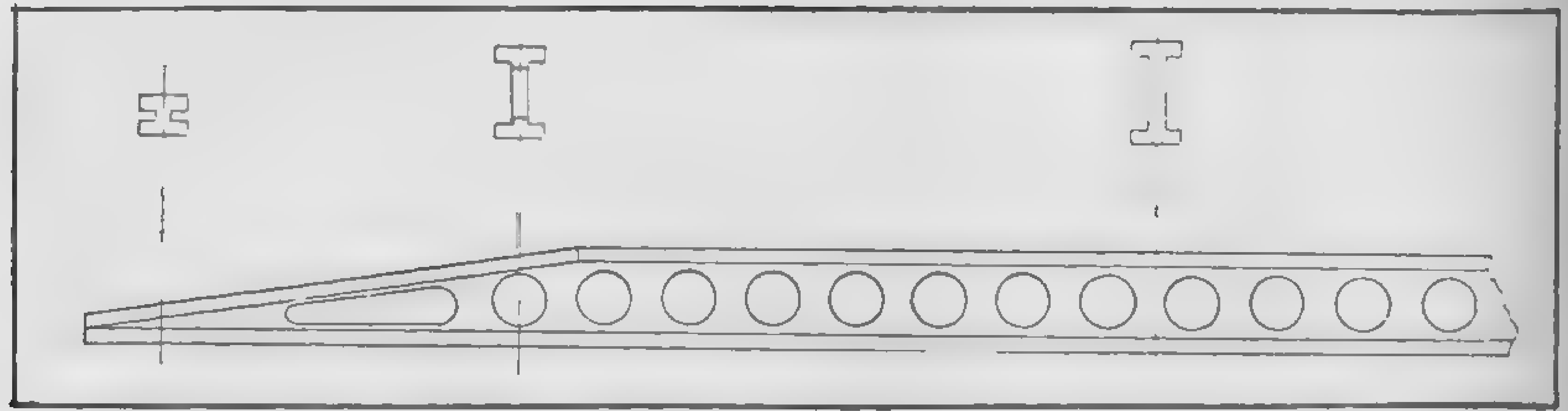


Fig. 11. Thin Wing Spar Made of Spruce in I Section with Cut-outs for Lightness

The spar in Fig. 3 is hollow and is made of two pieces of wood, which are doweled or fastened together with strips of hard wood.

Frequently, to avoid any chance of these two pieces slipping or coming apart in any way, strong linen tape is carefully wrapped and glued around the entire spar. This is then doped and covered with several coats of spar varnish and shellac to prevent the destroying effect of moisture. See Fig. 4.

Another spar which is also sometimes wrapped in the manner just described is shown in Fig. 5. This has a central strip of ash that is hollowed out slightly to make a modified I section. The hollowed portion is filled with steel strips. Two pieces of spruce are then added on either side for stiffening, and the spar is taped and varnished.

The spar shown as Fig. 6 is similar to Fig. 5 except that two pieces of spruce are hollowed out to make the I section and are then placed on either side of a steel strip.

The I section of the spar in Fig. 7 is made of ash and the side members are of spruce.

When the spar is placed so that it forms part of the entering edge of the wing, it is built in the manner shown in Fig. 8. It is similar in construction to Fig. 3.

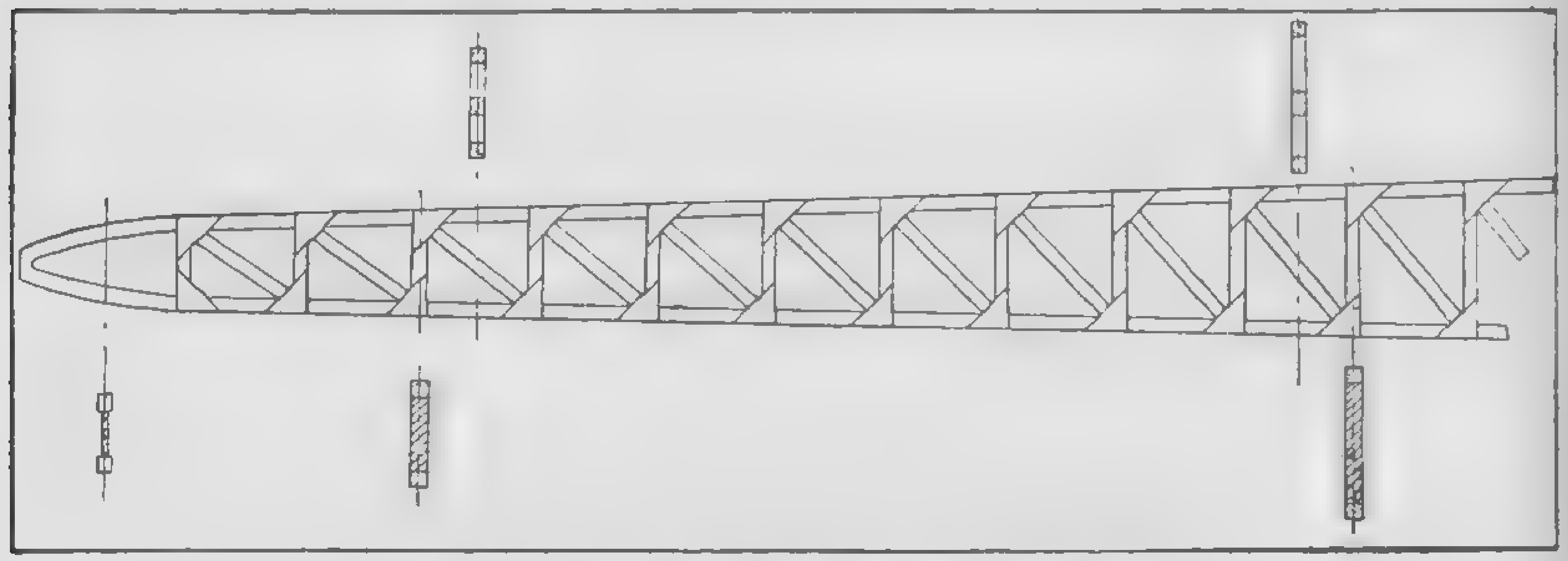


Fig. 12. Thick Wing Spar of the Truss Type





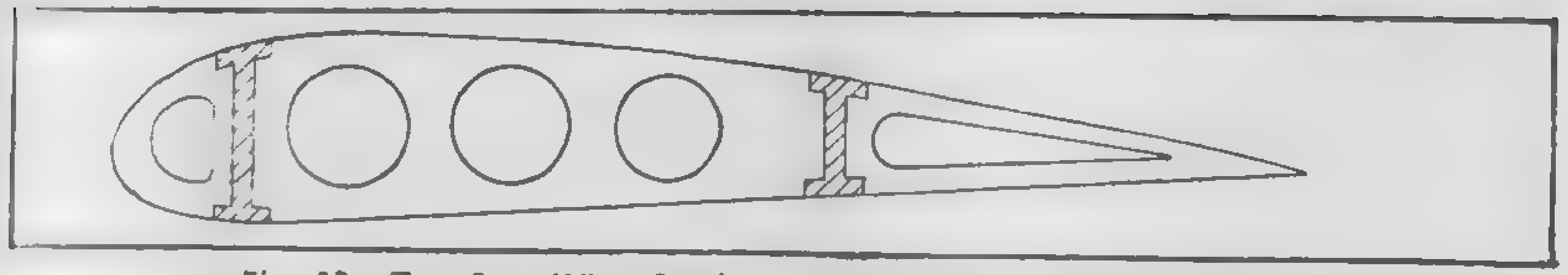


Fig. 13. Two-Spar Wing Section. The Shaded Portions are I Spars

When all-metal wing construction is used, spars are sometimes built of steel tubing, as shown in Fig. 9. Tubes of this sort are welded into the truss construction shown as Fig. 10.

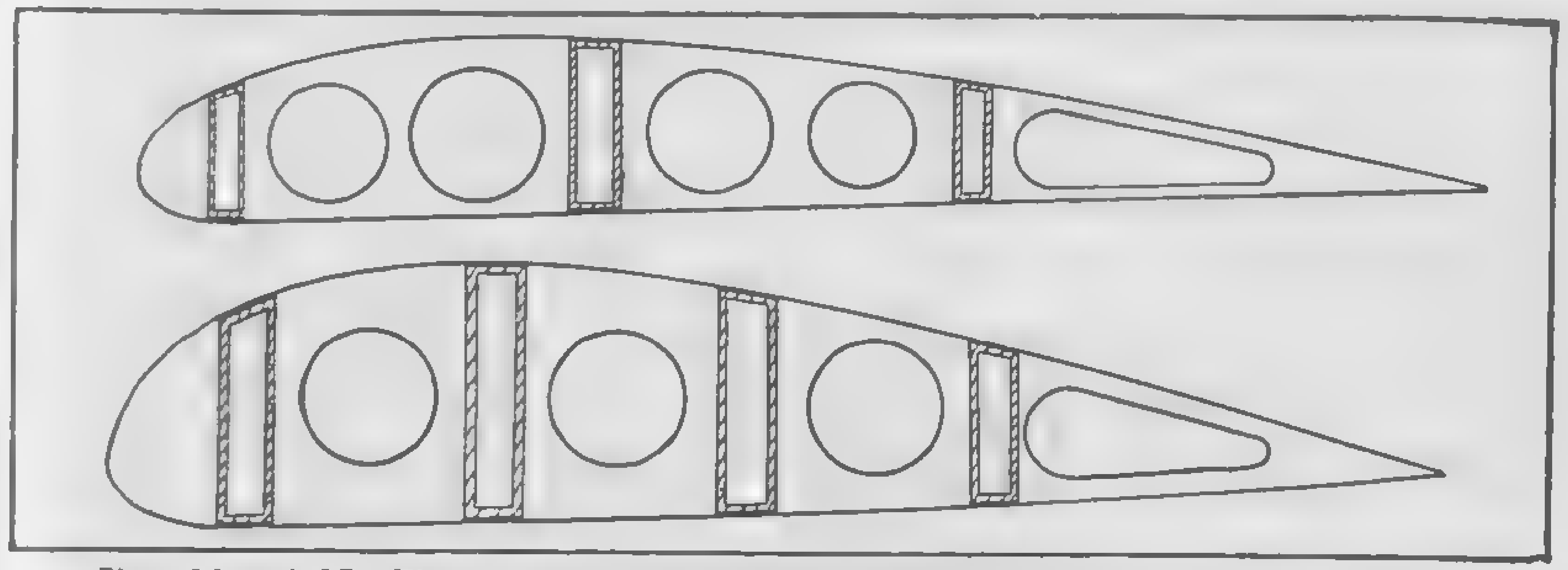
We know what a sectional view of a spar looks like. The longitudinal shape also varies. Fig. 11 shows a typical front spar for a thin wing airplane. Notice how this spar has not only been shaped as an I section, but has been cut out along its length to further reduce the weight.

Fig. 12 shows a typical thick wing front spar of the truss type. This view shows only one-half of the spar.

Generally the designers of wings use but two spars, as shown in Fig. 13. Other designers, however, use more, and some of the arrangements when more than two are used are shown in Figs. 14, 15, 16, and 17.

A cambered wing gives a much better lift than a flat wing, and it is necessary to make a wing thick enough for the introduction of spars. The necessary shape is given to the wings by the use of ribs. The ribs have an additional work to do; they take up the weight and transfer it to the spars. Figs. 16 and 18 show a wing with the ribs and spars in place.

Fig. 21 shows a single rib and how it is made up. The center of this rib is made of plywood, cut out to make it light and allow



Figs. 14 and 15. Three- and Four-Spar Wing Sections. Box-Type Spars Are Shown

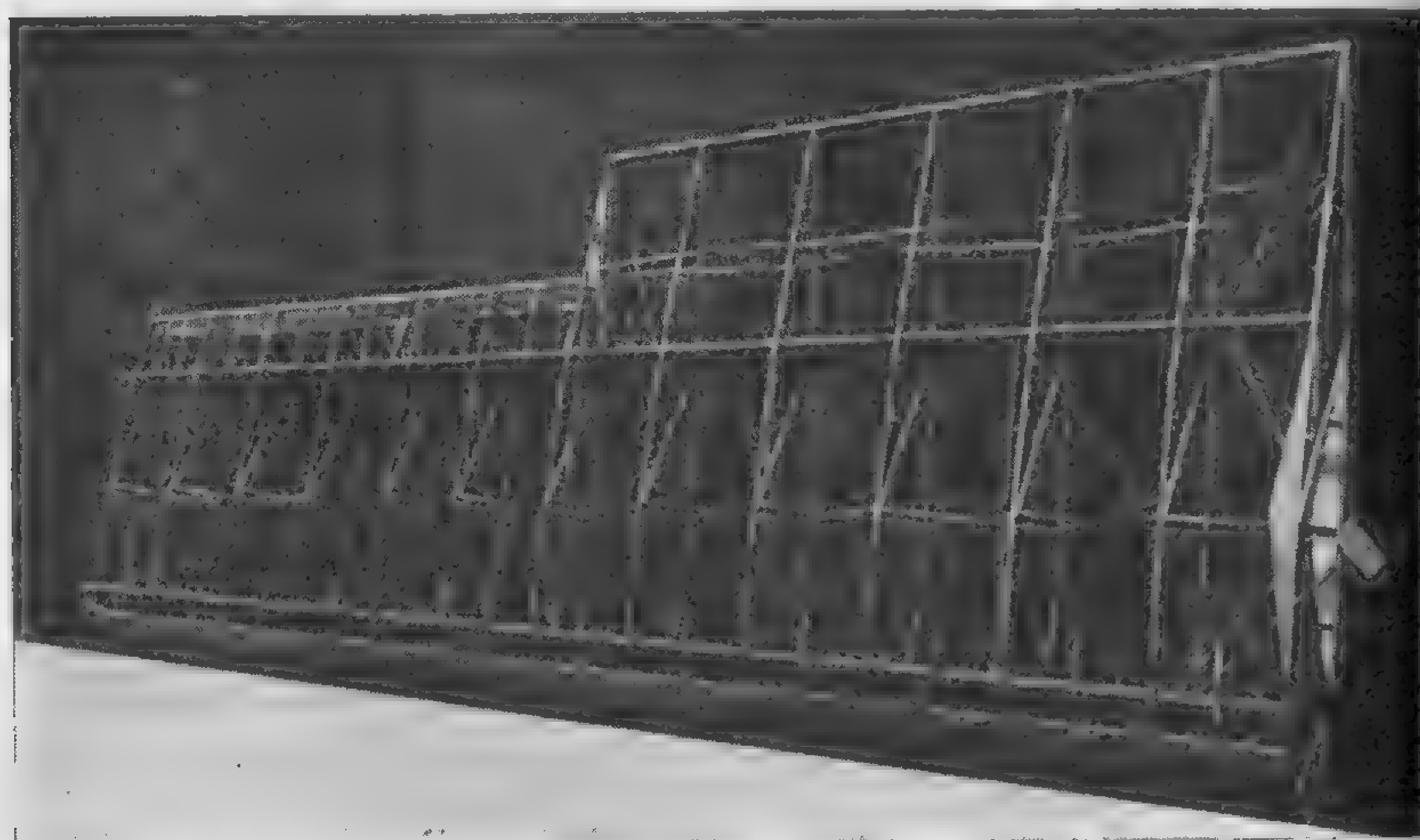


Fig. 16. Wing Construction on the Taylorcraft. Spars Are Built of the Finest Spruce, and the Ribs and Leading Edge of Corrosion-Resistant Nicraluminum. Fiber Bushings Are Used at all Points of High Loading. Note the Round Compression Members and Tension Wires

*Courtesy of Taylorcraft Aviation Corporation*

for cross braces. The plywood is cut to the proper camber and then a strip of wood about an inch wide and a quarter of an inch thick is nailed and glued to the plywood. This piece of wood is called the cap strip.

Other methods of building the ribs are shown in Figs. 22, 23, and 24. These methods are called truss construction and are accomplished in the case of wood construction by gluing and screwing all parts together.

Fig. 25 shows one way in which ribs are made when an all-metal construction is used.

Fig. 17. Center Wing Panel Assembly Line in the Plant of Republic Aviation Corporation, Farmingdale, New York

*Courtesy of Republic Aviation Corporation*





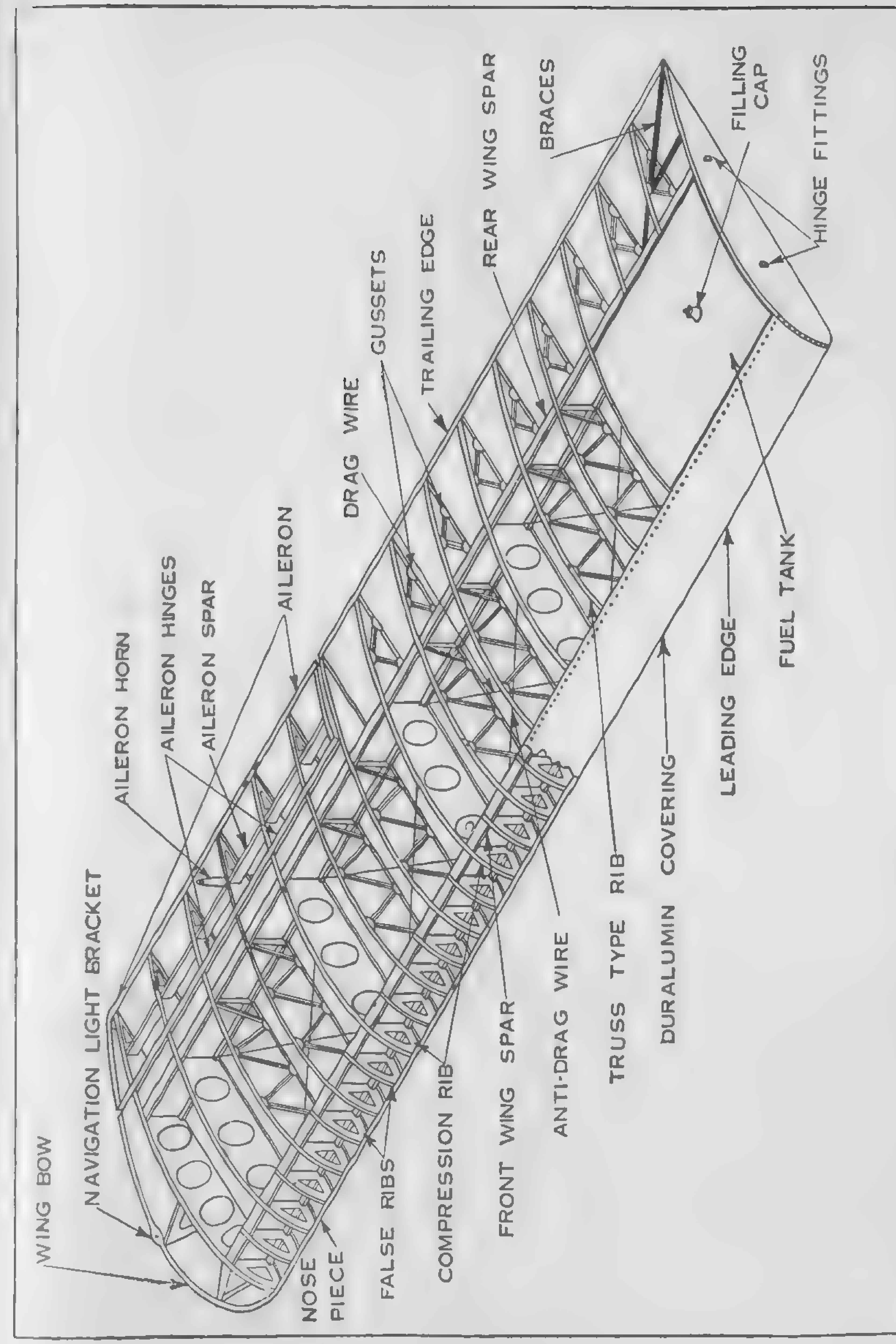



Fig. 18. Study This Drawing Carefully so That You Will Be Entirely Familiar with the Names of the Various Parts of a Wing Structure and Their Relation One to the Other. Notice Particularly the Difference in the Construction of the Compression Ribs

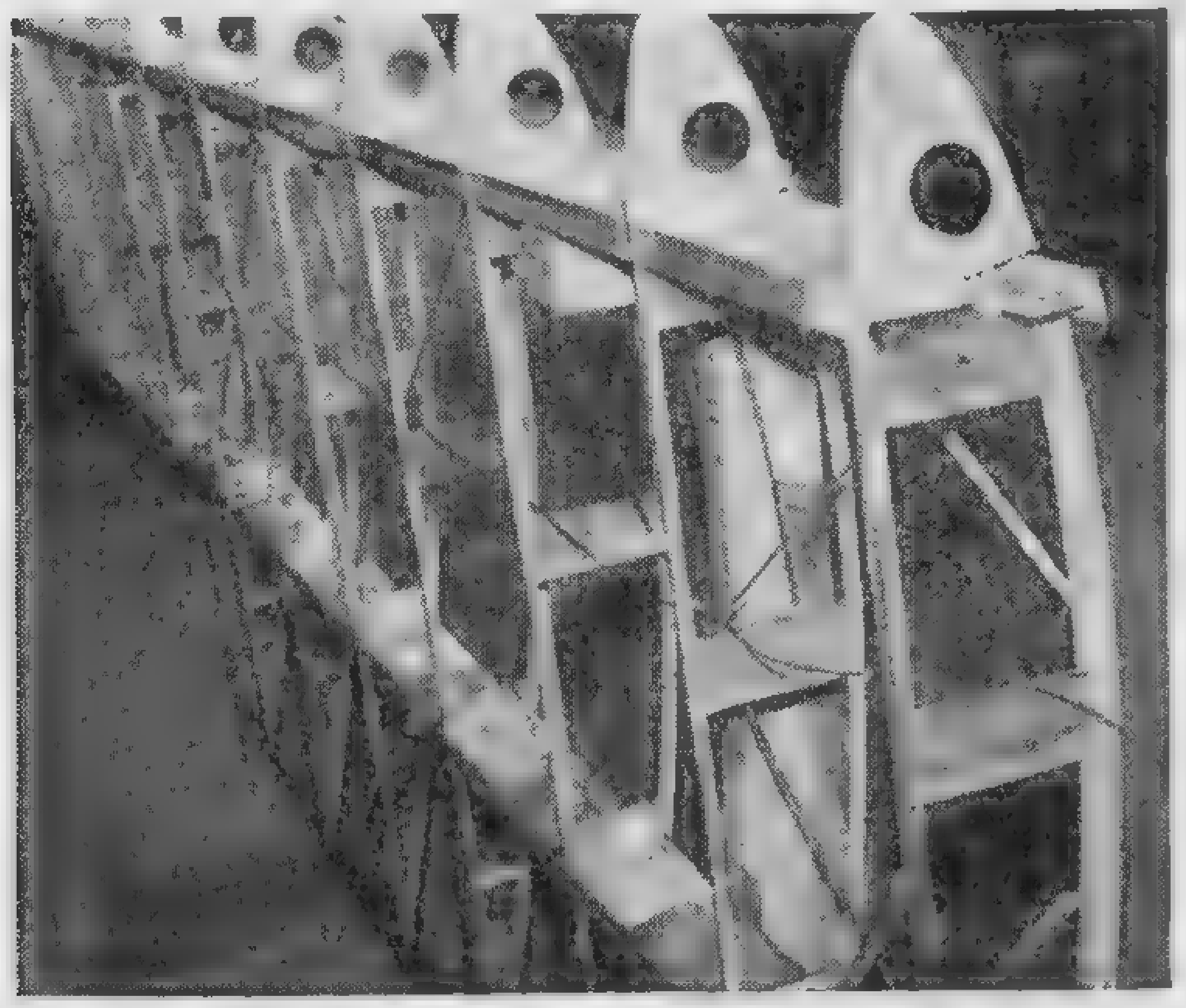


Fig. 19. Internal Structure of the Wing of an All-Metal Luscombe Monoplane, Which Uses Metal Wing Spars Instead of Wood

*Courtesy of Luscombe Airplane Corporation*

Turn to Fig. 19 and note particularly the construction of this wing. Each panel is constructed of two extruded I-beam Dural spars, and to these spars are riveted Dural ribs, the cap strips of which are **T**-shaped extrusions. Nose ribs are simple Dural stampings, and the leading edge covering is thin Dural. Each wing spar has a 3½-foot subspar of lighter Dural at the end.

In this type of plane, ailerons, elevators, and rudder consist of frameworks of channel section Dural covered by beaded 17ST Alclad. Fin and stabilizer are of the same construction and are covered with smooth 17ST Alclad. All control surfaces are full cantilever, requiring no bracing wires.

The fuselage construction of this is a full monocoque of .032 17ST Alclad skins riveted to stamped Dural oval-shaped bulkheads.

The wing is now ready to be covered. The wing covering for

Fig. 20. Line-up of Outer Wing Assembly Jigs, Showing Wings in Construction at The Glenn L. Martin Company Factory

*Courtesy of The Glenn L. Martin Company*





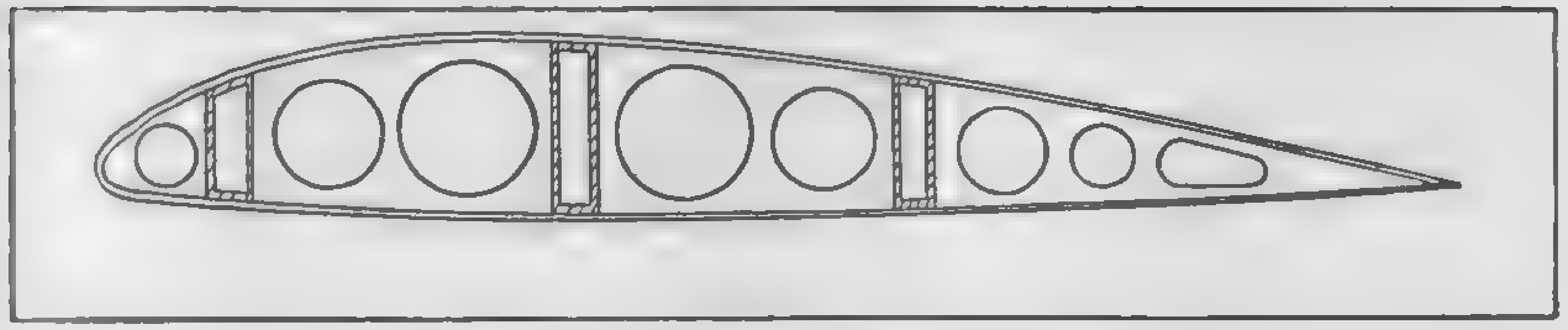


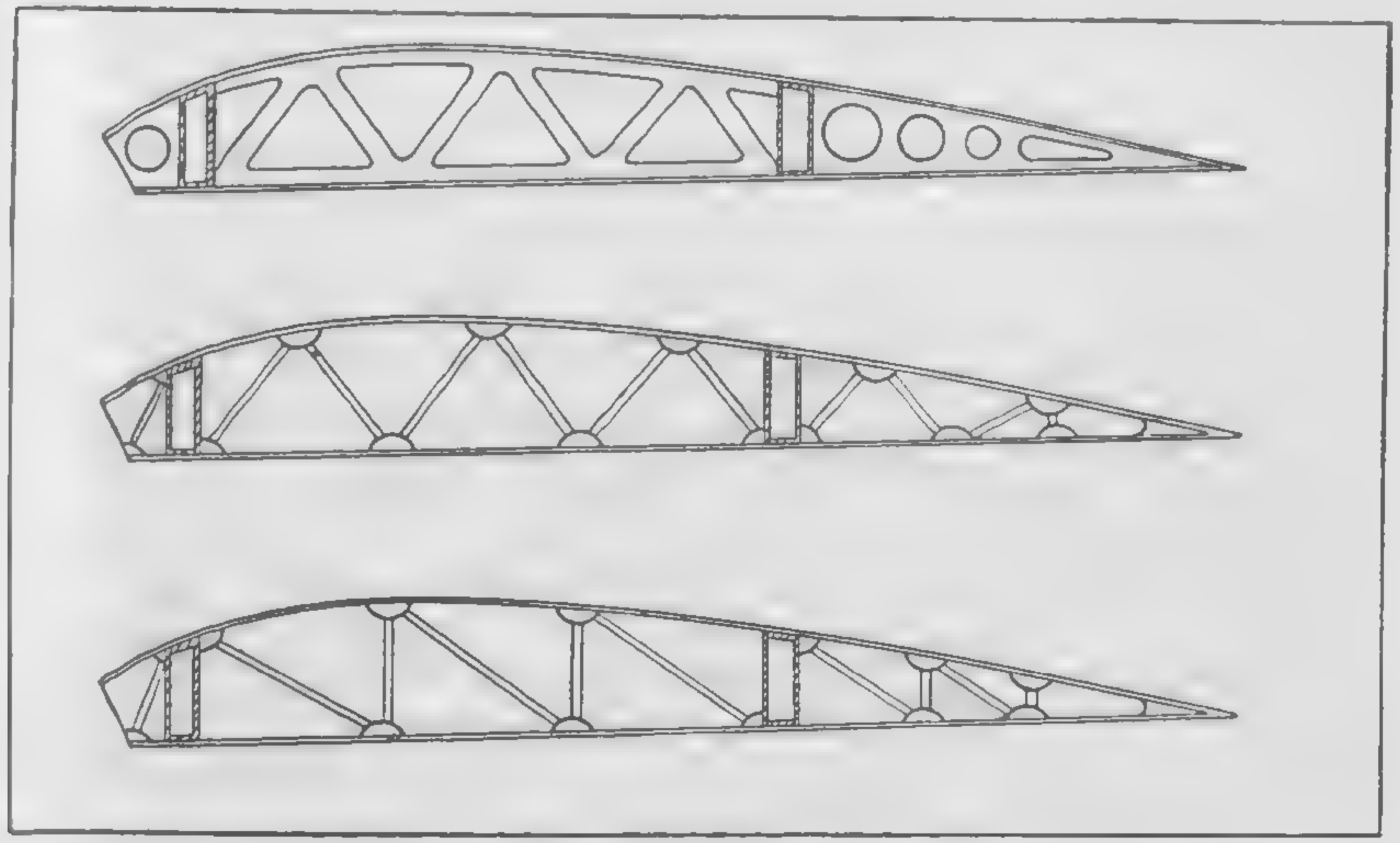
Fig. 21. Rib Having a Center of Plywood

wood rib construction is wood veneer, or fabric covered with dope. Fig. 26 shows a completed airplane of all-metal construction including metal wing covering.

There are two distinct classes of wings. Those which do not require external bracing of any kind but depend upon the strength of the spars and internal bracing, and those which depend partly on external bracing in the form of struts and bracing wires for their strength.

The wing of the Taylorcraft plane, Fig. 16, shows a light, sturdy construction using wood spars and metal ribs.

Fig. 17 shows the center wing panel assembly line in the plant of the Republic Aviation Corporation, Farmingdale, New York. The two panels in the foreground are the center wing sections of two airplanes. They are constructed in a jig in duplicate pairs for operating convenience. This panel has spar construction and



Figs. 22, 23, and 24. Different Types of Rib Construction. The Stub Nose Is for the Purpose of Adding the Nose Piece

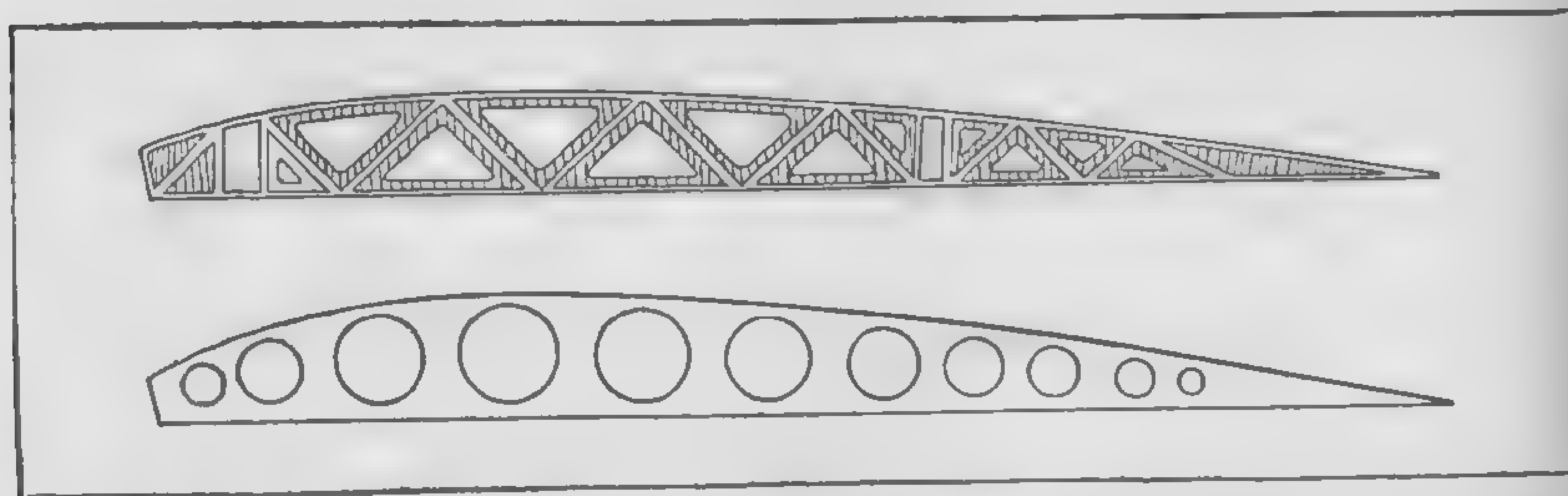


Fig. 25. The Rib Shown at the Top Is Made of Corrugated Sheet Aluminum Alloy, Stamped Out. The Rib Shown in the Lower Part Is Made of Plain Sheet Aluminum Alloy, also Stamped Out

is covered with an aluminum alloy skin, the entire being riveted together. In the Republic pursuit airplanes, the center panel is an integral gas tank for the airplane. In other words, each of these sections is not only part of the wing, but also carries most of the gasoline supply for the airplane. The projecting portions in the top of the sections are the flaps, or air brakes, which slow down the plane for landing.

Wings covered with metal may be constructed very much the same as wings covered with wood veneer, except that the spars and ribs are constructed of steel or duralumin tubing. The metal covering is riveted to the spars and ribs. Many modern metal-wing airplanes are skin stressed, which means that the metal covering is not only a cover, but it carries part of the load, reducing the number or size, as well as the strain, on these spars or other longitudinal members. Fig. 26.

**Fig. 26. An All-Metal Plane in Flight**
*Courtesy of Pennsylvania Central Airlines Corporation*





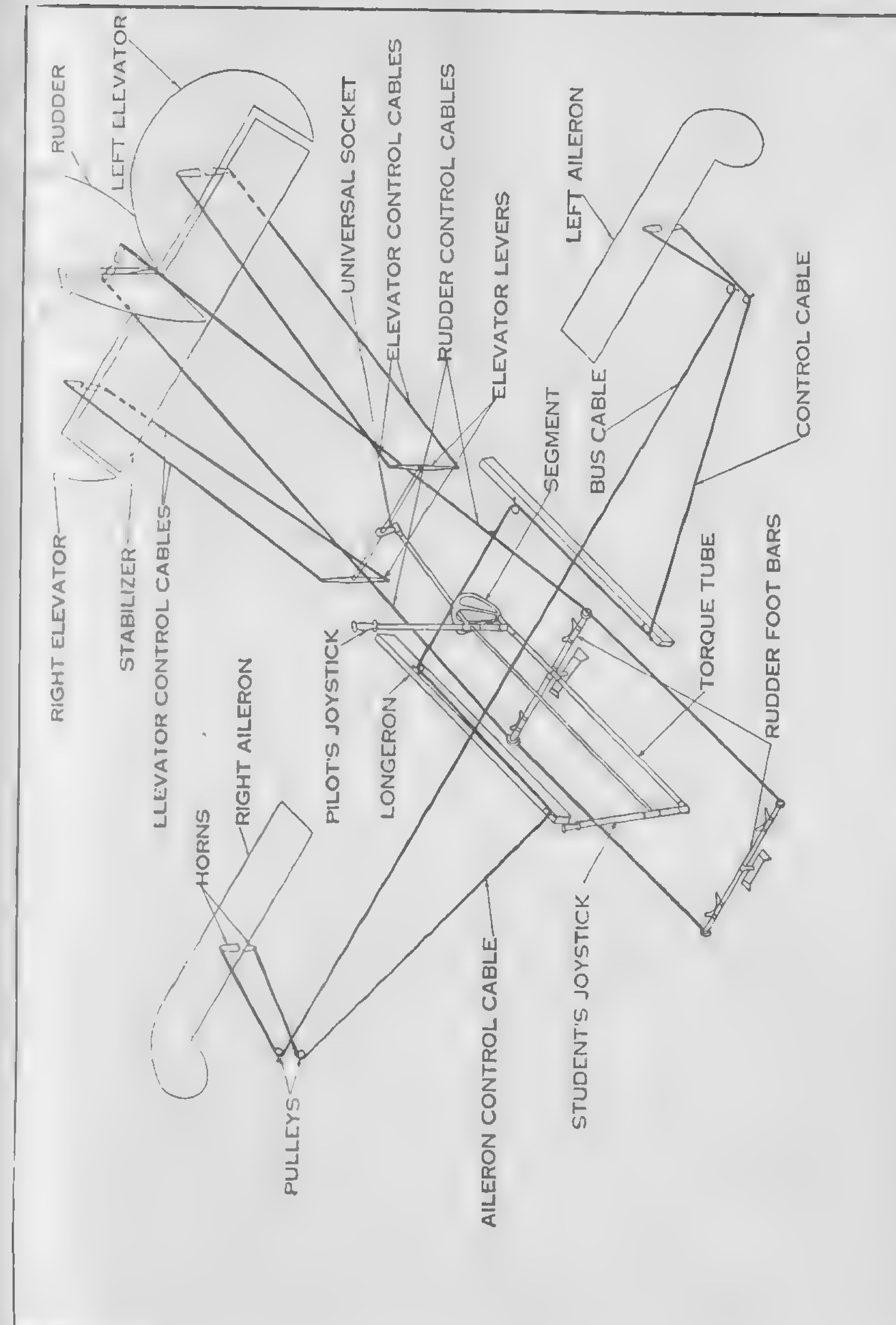



Fig. 27. The Control Cables Are Connected to the Segment. This Is Difficult to Show in a Drawing of This Kind, and It Is Suggested That You Take All Opportunities to See How This Is Done on Each Airplane

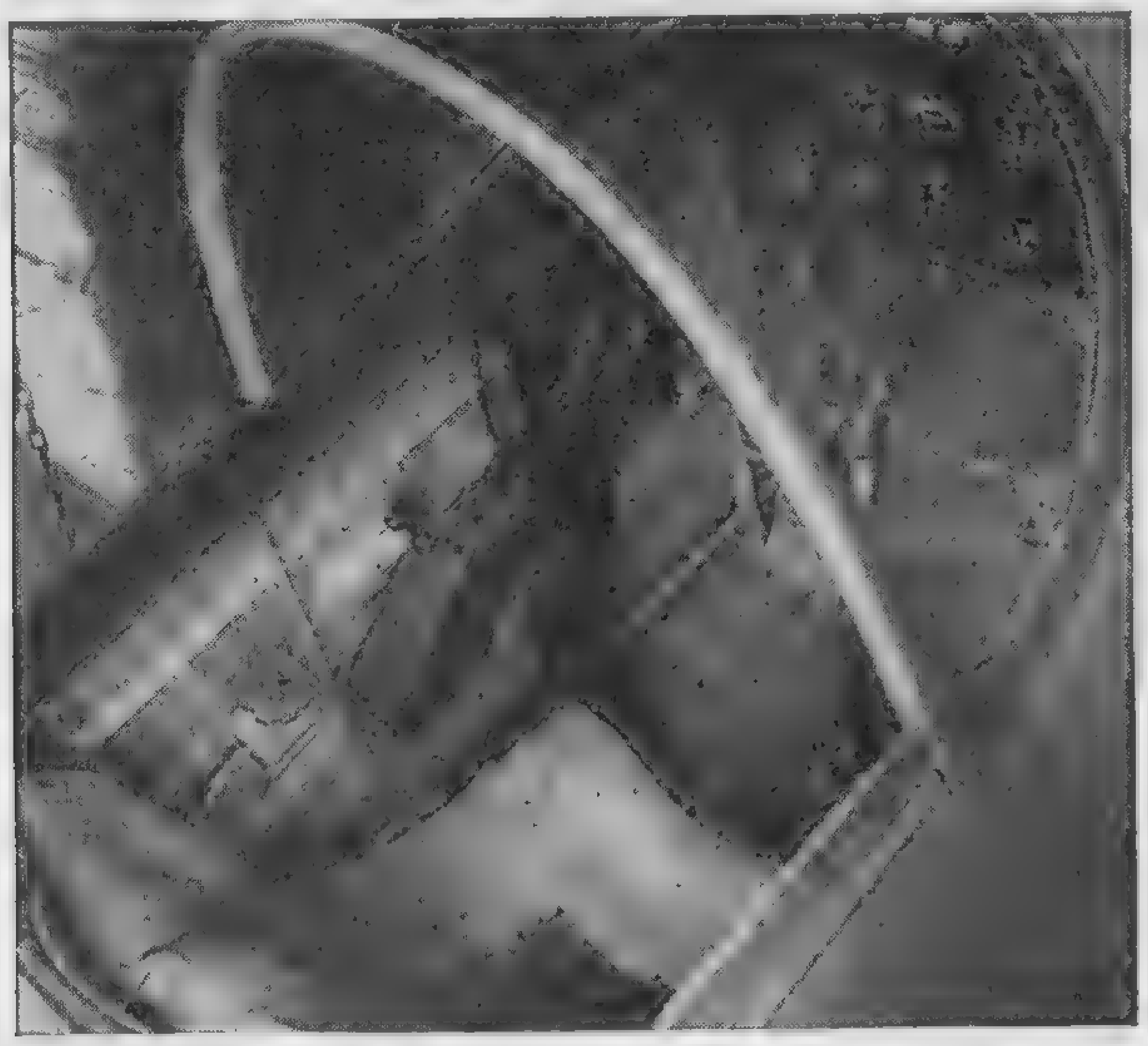


Fig. 28. Cockpit of Curtiss-Wright 21 Interceptor. This Is a Single-Place One-Man Fighter Airplane Designed for Rapid Climb, Together with High Speed and Excellent Maneuverability
*Courtesy of Curtiss-Wright Corporation*

The ailerons, which control the lateral stability of an airplane, are more frequently constructed of steel or aluminum alloy, although some manufacturers continue to use wood. They are cambered symmetrically with the wings which they are to fit, and are covered.

Fig. 29. Fuselage Half Nose on Model 167-F of the Martin Plane. Right Side Is Ready for Longitudinal Splice, Showing Dual-Wheel Control and Other Equipment Installation. Note the Monocoque Construction of the Hull
*Courtesy of The Glenn L. Martin Company*





Control of the ailerons, elevators and rudder is obtained by one of two systems. The first to be described is the *stick control* shown in Fig. 27. If the control stick is moved to the right, the control cable moves to the right, pulling the left aileron down, which raises the right aileron the same amount by pulling on the bus cable, see Fig. 27.

The other form of aileron control is the *wheel* or *"dep" control,* illustrated in Fig. 29. Instead of pushing a stick to the right or left,

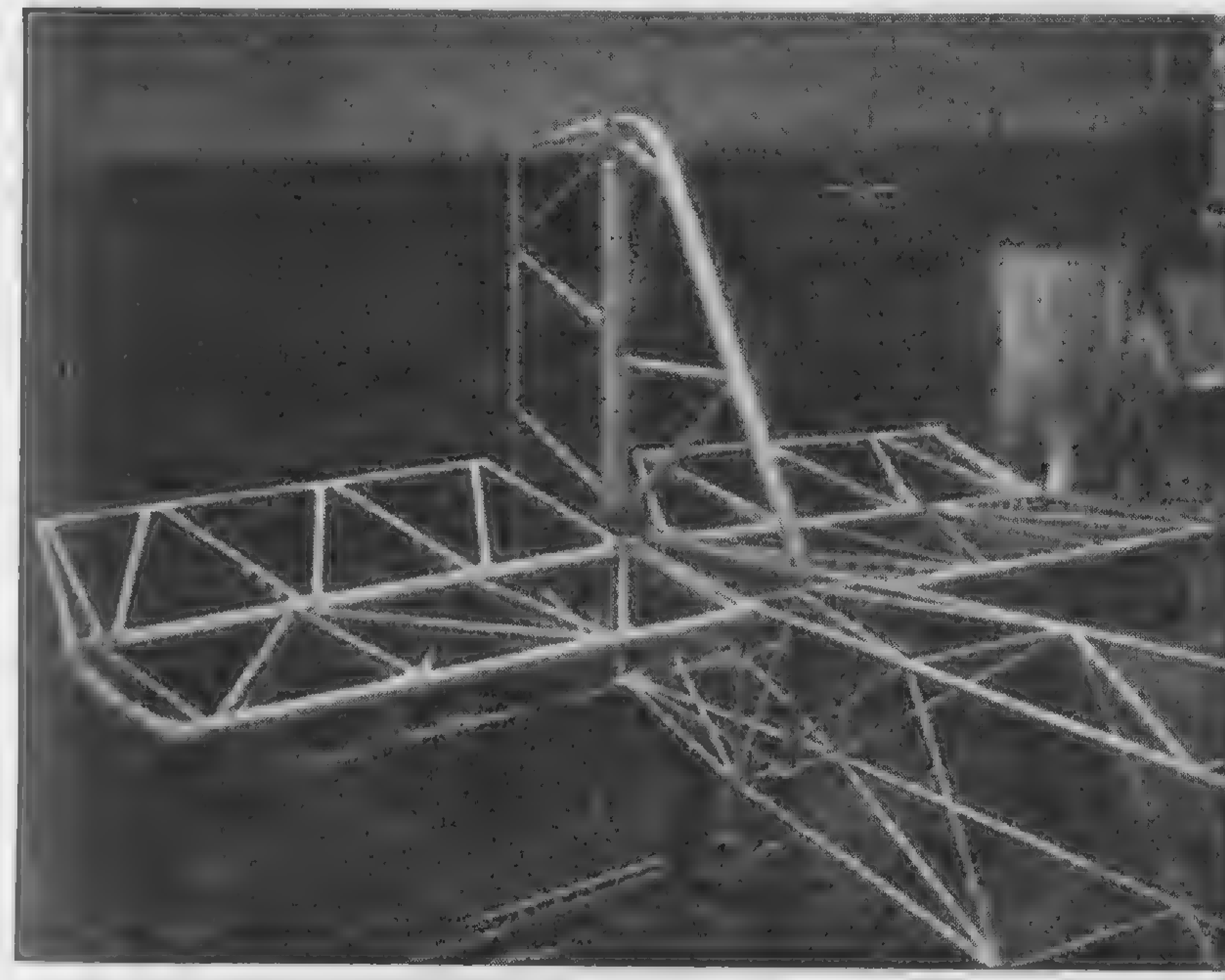


Fig. 30. Stamped "Alcad" Tail Groups—Consisting of Vertical Fin, Rudder, Horizontal Stabilizer and Elevators
*Courtesy of Fairchild Airplane Manufacturing Corporation, Farmingdale, L. I., N. Y.*

the wheel is turned, the cable being wound up on one side and payed out on the other. On large transport ships of great weight this wheel is sometimes geared to make movement easy. Another type of aileron control which is similar in action, substitutes steel rods for the wire cable. In either of the controls just described, movement of the elevators is obtained by moving the stick or wheel backward or forward. The rudder, as will be noted from the drawing, Fig. 27, is connected to a rudder bar or pedal, which is actuated by the feet.

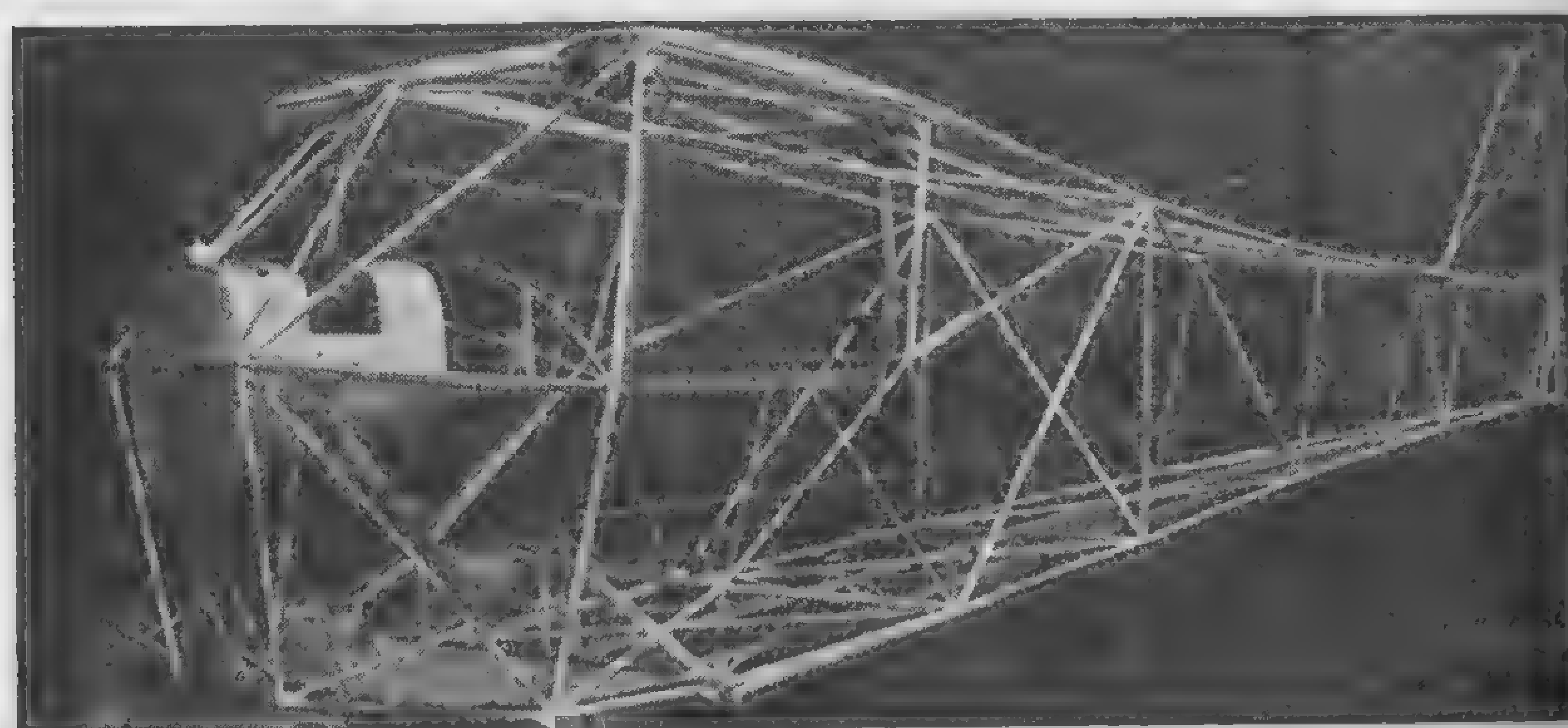


Fig. 31. Taylorcraft Metal Tube Fuselage. Scientifically-braced Seamless Steel Tubes Are Welded into a Four-Longeron Fuselage

In nearly all instances the control cables are on the inside, coming out just in time to connect to the horns. This is done to reduce the parasite resistance.

The horizontal stabilizer follows the same general line of construction as the wings. It has camber (usually), front and

Fig. 32. The Sports Plane Goes into Mass Production. The Lengths of Light Steel Tubing, Cut to Proper Size, Are Fitted and Welded Together in the Jig

*Courtesy of Taylorcraft Aviation Corporation*





rear spars, ribs for transmitting the load from the wing covering to the spars, and fittings for adjusting the angle of incidence.

Fig. 30 shows a horizontal stabilizer and elevator constructed entirely of metal. The elevator control, as has been pointed out, is similar to the control of the aileron, only more simple. It consists chiefly of a connection by wire to the stick or bridge. See Fig. 27 for the method of operation.

The rudder and vertical fin follow much the same construction as the other tail surfaces, whether of wood or metal construction.

Fig. 33. The Body of the Taylorcraft Begins to Take Form with the Welding Together of the Sides of the Ship. The Framework Is Then Swabbed with a Chemical Solution to Prevent Rust and Corrosion

*Courtesy of Taylorcraft Aviation Corporation*

You will notice in Fig. 27 that the top part of the rudder, the outside ends of the elevators and ailerons extend somewhat. These are called balanced controls, and are for the purpose of making them more sensitive to the action of the air flow.

One of the most difficult problems confronting the designer of an airplane is the design of the fuselage. It must be constructed first of all so that there is adequate room for the motor and all its accessories; these must be easily available for inspection and repair. The pilot's seat or seats must be located so that excellent vision

may be obtained. In passenger transport planes consideration must be given to the comfort of the passengers. In mail and express planes the design must include as much room as possible for the pay load. The plane, loaded or unloaded, must balance aerodynam-

Fig. 34. Boeing Stratoliners. Note the 4-Engine Transport at the Extreme Left in Upper View. Lower View Shows the Large Amount of Room in the Cabin for the 33 Passengers that the Plane Will Carry. The Stratoliner's Fuselage—11½ Feet in Diameter—Is Completely Circular from Nose to Tail. Below the Floor Are Cargo Holds and an Accessory Compartment

*Courtesy of Boeing Aircraft Company, Seattle, Washington*





Fig. 35. The Fuselage of a 33-Passenger Boeing Stratoliner Takes Its First "Flight" via Overhead Crane from the Assembly Jigs to the Final Assembly Floor, where It Will Be Joined by Wings, Tail, Surfaces, and Other Assemblies

*Courtesy of Boeing Aircraft Company, Seattle, Washington*

ically. Furthermore, the fuselage must be streamlined so as to keep down parasite drag as much as possible.

Three distinct types of fuselage construction are now in use: The metal-tube type; the monocoque; and the semi-monocoque.

Fig. 31 shows steel tube construction. This type eliminates the use of fittings to hold the struts in place, as the tubes are put into a jig, and after being accurately bent to their proper places are welded. A weld properly made has the same effect as though the pieces were made originally as one. Fig. 32 shows an all-metal fuselage being constructed in a jig to eliminate the possibility of anything but absolute accuracy in its construction. A steel tube fuselage may be covered with fabric or aluminum alloys.

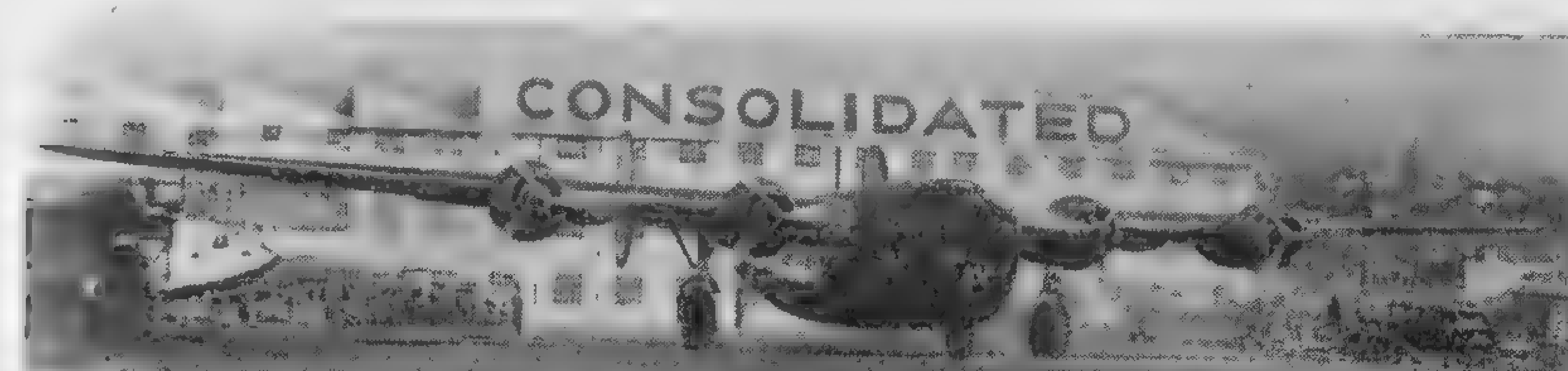



Fig. 36. Built for the U. S. Army Is This Huge Land Bomber, the XB-24, or the Consolidated Model 32. Its Four Engines Are Rated at 1,200 Horsepower Each. It Shows Its Split-Type Retractable Tricycle Landing Gear with Nose Wheel

*Courtesy of Consolidated Aircraft Corporation, San Diego, California*

Fig. 37. Wheels, Brakes, Tires, Shock Absorbers, and Retraction Gear Are Given Particular Attention when American Airlines Prepares Its Fleet of Flagships for Flying. Mechanics Are Putting a New Tire on a Wheel Preparatory to Returning It to Service
*Courtesy of American Airlines, Inc.*

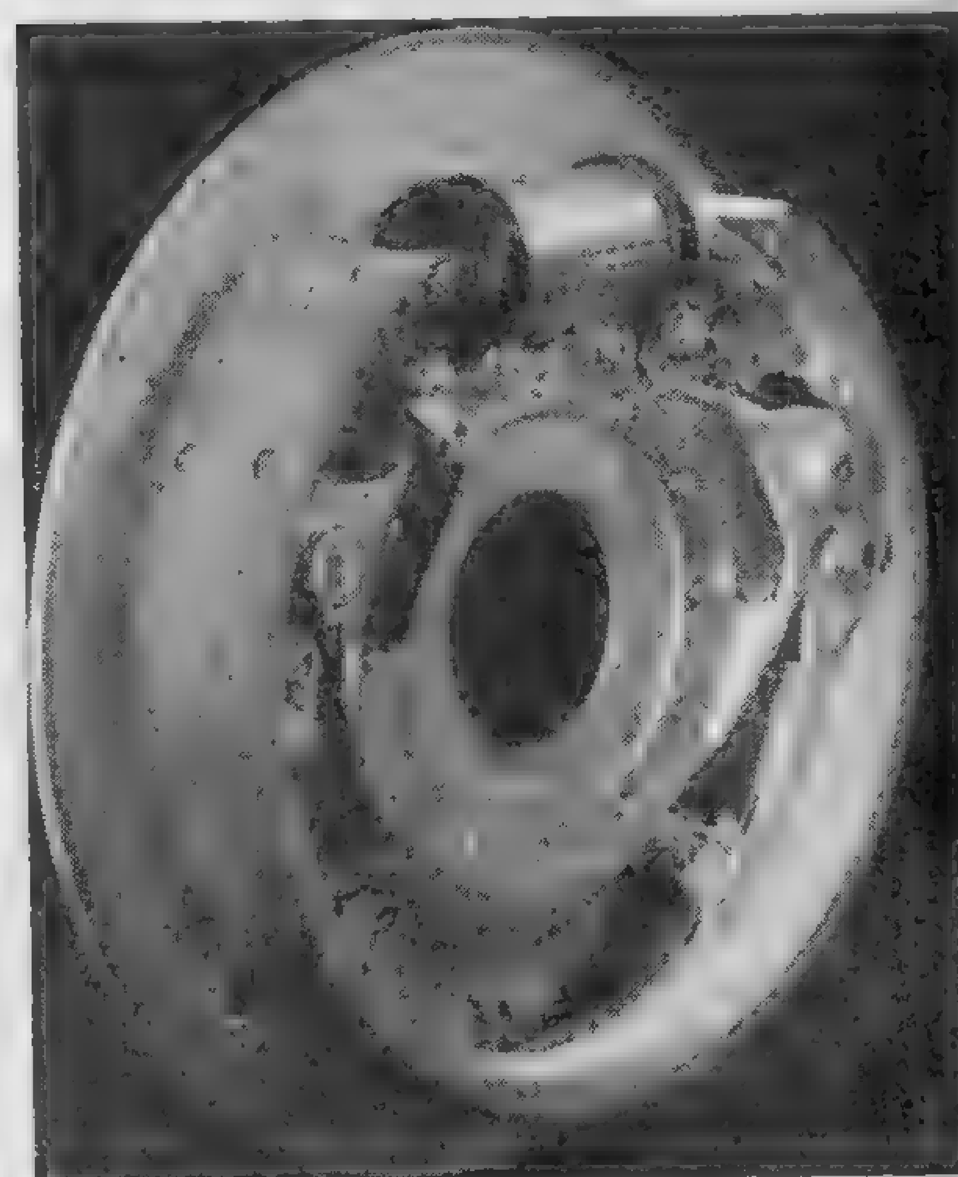


Fig. 38. Hayes Reversible Hydraulic Brake

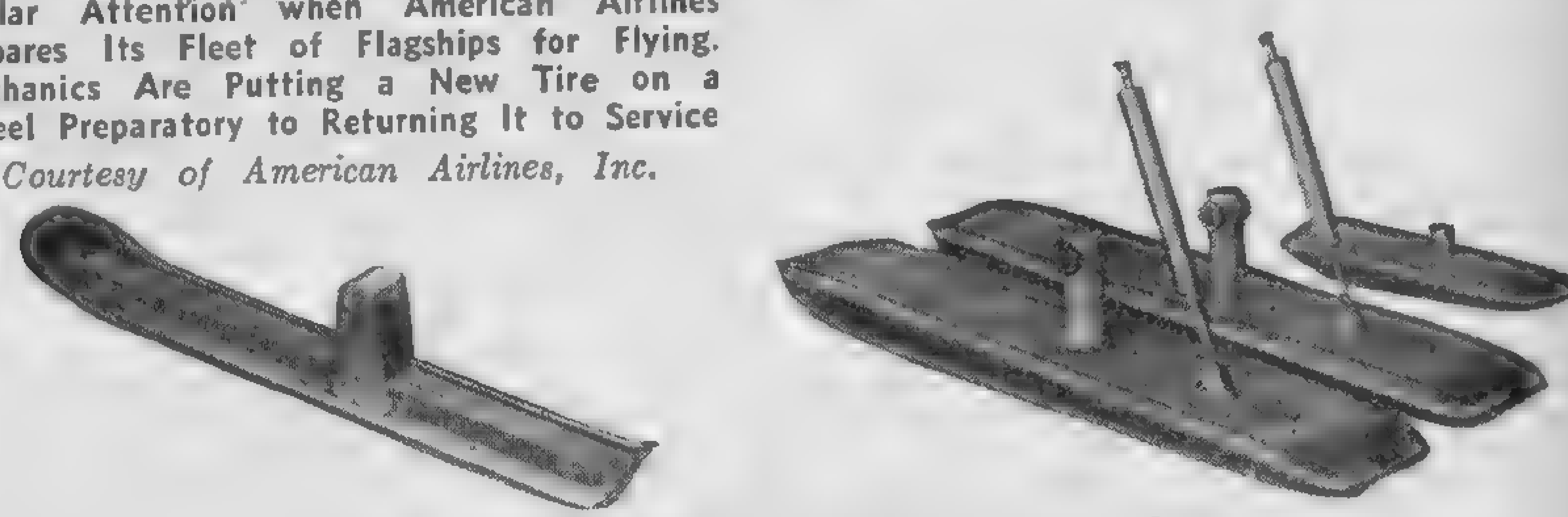


Fig. 39. Ski Attachment for Landing on Ice or Snow
*Courtesy of Federal Aircraft Works*

Fig. 40. Lockheed B-14 Long-Range Reconnaissance Bomber
*Courtesy of Lockheed Aircraft Corporation*





Fig. 41. Showing the Bell Airacobra Fighting Plane with Front-Wheel Landing Gear
*Courtesy of Bell Aircraft Corporation*

From the illustrations shown in Figs. 34 and 35, it will be seen that these huge STRATOLINERS are built with the aid of jigs and show a tunnel-like construction. A series of circular and longitudinal stiffeners and the floor construction constitute the main stress-bearing members of the fuselage. The skin covering is attached to the fuselage framework by riveting and welding and adds much to the strength of the plane.

The semi-monocoque is built of longerons and bulkheads, and is covered with veneer or aluminum alloy. The veneer is put on in sheets instead of being wrapped, as on the full monocoque. In this type of fuselage the longerons take the bending stresses and the veneer takes the shearing stresses.

The weight of an airplane when resting or taxiing over the ground is carried by the landing gear and tail skid.

Fig. 42. Landing Gear Equipped with Hydraulic Shock Absorber Brake and Low Pressure Tire
*Courtesy of The Goodyear Tire & Rubber Co.*

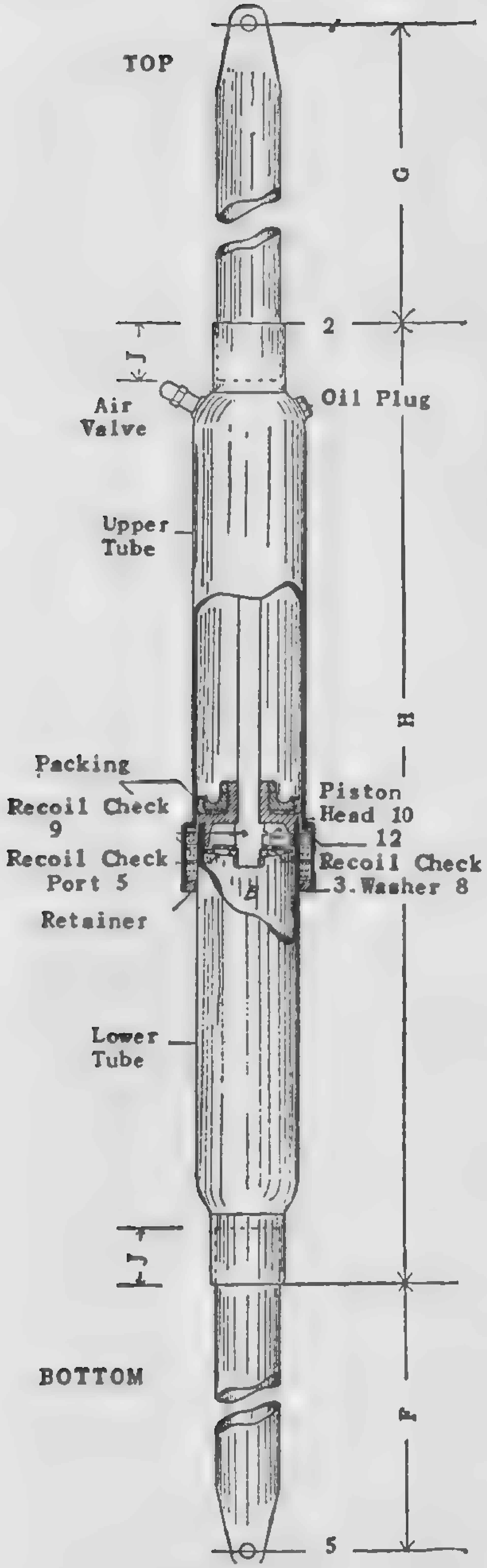



Fig. 43. Diagrammatic View of Gruss Aerol Strut Shock Absorber
*Courtesy of Gruss Air Spring Co., of America, San Francisco, Calif.*

The "Split-type Landing Gear" is illustrated in Fig. 36. Each wheel has a separate stub axle. The elimination of the full axle reduces the chances of nosing over when landing or taxiing.

The wheels are disc constructed and run on pneumatic tires comparable to automobile tires. Brakes are applied to the wheels to shorten the roll of the plane after landing. The advantage of the brakes in coming to a quick stop is invaluable. They are also of untold advantage in aiding the airplane to turn around while on the ground, since the brakes on both wheels act independently of each other. Fig. 38 shows the reversible hydraulic brake which is used on a number of airplanes. Some planes are provided with a ski attachment for landing on ice or snow, Fig. 39.

Retractable landing gears, Figs. 40 and 41, are used on most military and transport planes and on all amphibians. They consist of wheels and struts which are attached to a mechanism, usually consisting of a worm gear or a hydraulic cylinder, which is primarily operated by electricity or hydraulic power, but an emergency hand operation system is always provided within easy reach of the pilot. When the airplane is in flight, the wheels are





cranked up. When alighting on land, they are lowered into position for landing.

The development of the shock absorber for airplanes has perhaps been an even greater boon to the aviator than the development of the shock absorber for the automobile has been to the motorist. It absorbs the landing shocks and not only affords a greater comfort to the passengers but reduces the expense of upkeep and prolongs the life of the plane and motor. A great part of the deterioration of plane and motor is due to landing shocks.

Shock absorbers are of three general types: The rubber cord, the compression disk, and the air and oil cylinder.

The rubber cord, which was the earliest common type, consists of a bundle of small rubber cords which are covered with fabric.

Fig. 44. Showing the Landing Gear of a Fairchild Plane
*Courtesy of Fairchild Aircraft*

Compression disks are made of a special rubber compound which is quite resilient. These, as their name indicates, take the shock in compression rather than in tension, as is the case with the shock cord.

Most large planes are equipped with the air-and-oil type of shock absorber. Fig. 43 will show you how the Gruss aerol shock absorber works. This shock absorber has only one moving part; a piston which slides up and down in a steel outer housing. This outer housing labeled upper tube in the diagram is filled with compressed air. The lower tube, marked "B" in the diagram, is filled with oil. When the plane lands, the shock of landing causes the lower tube "B", terminated by the piston head, to slide upward against the cushion of compressed air, which absorbs the shock.

When this occurs, as you can see from the diagram, the space in the lower tube marked "B" is decreased, and the space above the flat head on the recoil check rod marked "C" is enlarged; this forces the oil upward through the recoil check ports. After the shock of landing has spent itself, the compressed air drives the piston head downward. The oil is caught between the bottom of the piston head and the disk attached to the end of the recoil check rod. It cannot escape through the recoil check ports as readily as it flowed in, because the recoil check washers have closed over the openings and it is squeezed back slowly to the lower tube "B". The compressed air, then, is used to absorb the shock of landing, and the oil is used to take up the rebound.

The tail wheel takes the shock of the tail when landing and supports and protects the fuselage when taxiing. This wheel also normally is provided with shock absorbers.

Usually the tail wheel is connected to the rudder bar or pedals so that its movement may be controlled by the pilot and so becomes a directional aid in taxiing.

## METHODS OF FABRICATION

Modern metal construction differs from the more familiar welded steel tube fuselage construction or spar and rib wing construction. Metal airplanes of today are *skin stressed.*

In both wing and fuselage construction the heavy type wing spar or longeron has been replaced by light metal stiffeners. The comparatively heavy metal skin is braced by these stiffeners so that the main load is actually carried by the skin of the airplane, instead of by wing spars or fuselage longerons.

This construction is illustrated in Fig. 34. While aluminum alloys are the most widely used material for both skin and stiffeners, stainless steel has entered the field to some extent. The resistance of stainless steel to corrosion, especially in salt water, has overcome its high cost, particularly for seaplane work.

Aluminum alloy structures are generally riveted throughout, using either the round head or the more expensive flush type rivet construction. The flush type rivet reduces skin resistance and so increases operating speeds and thereby reduces operating costs.





The speed is important for military work, while the reduction in operating costs is of primary interest to the commercial operator.

Metal construction is particularly adaptable to mass production methods. The increased demand for airplanes will undoubtedly increase its use even in the lighter type of aircraft. The main disadvantage of this construction is (a) the inability of the average repair station to repair even minor damage, and (b) the high cost of such repairs when proper facilities are available. Small

**Fig. 45. Installation of De-Icing Boots on the Wings Is a Major Step in the Preparation of Airplanes for Winter**
*Courtesy of American Airlines, Inc.*

holes or even dents can greatly reduce the strength of the skin-stressed wing and require an expensive, lengthy repair.

On the other hand, metal construction does not deteriorate from exposure to the elements and is not as liable to damage as a fabric-covered surface.

**Sheet Metal Forming.** The metal covering found on airplane wings, cowling, fairings, and in certain types of airplane fuselage, such as the runners, stringers, etc., also ribs, tanks, and many other parts of an airplane are fabricated from sheet metal, both steel and aluminum being used.

Aluminum is used extensively and it is formed into various shapes in a number of different ways. It can be formed into the desired shape by passing sheets or strips between rollers. It can be made in extruded shapes of many varieties. In this method the plastic metal is pushed through a die of the required form. Aluminum can be die cast, which consists of pouring metal into dies of the required shape. Aluminum also can be forged.

Many sheet metal shapes are made in presses under very high pressure, which forces the metal to fill or conform to a die of the required shape.

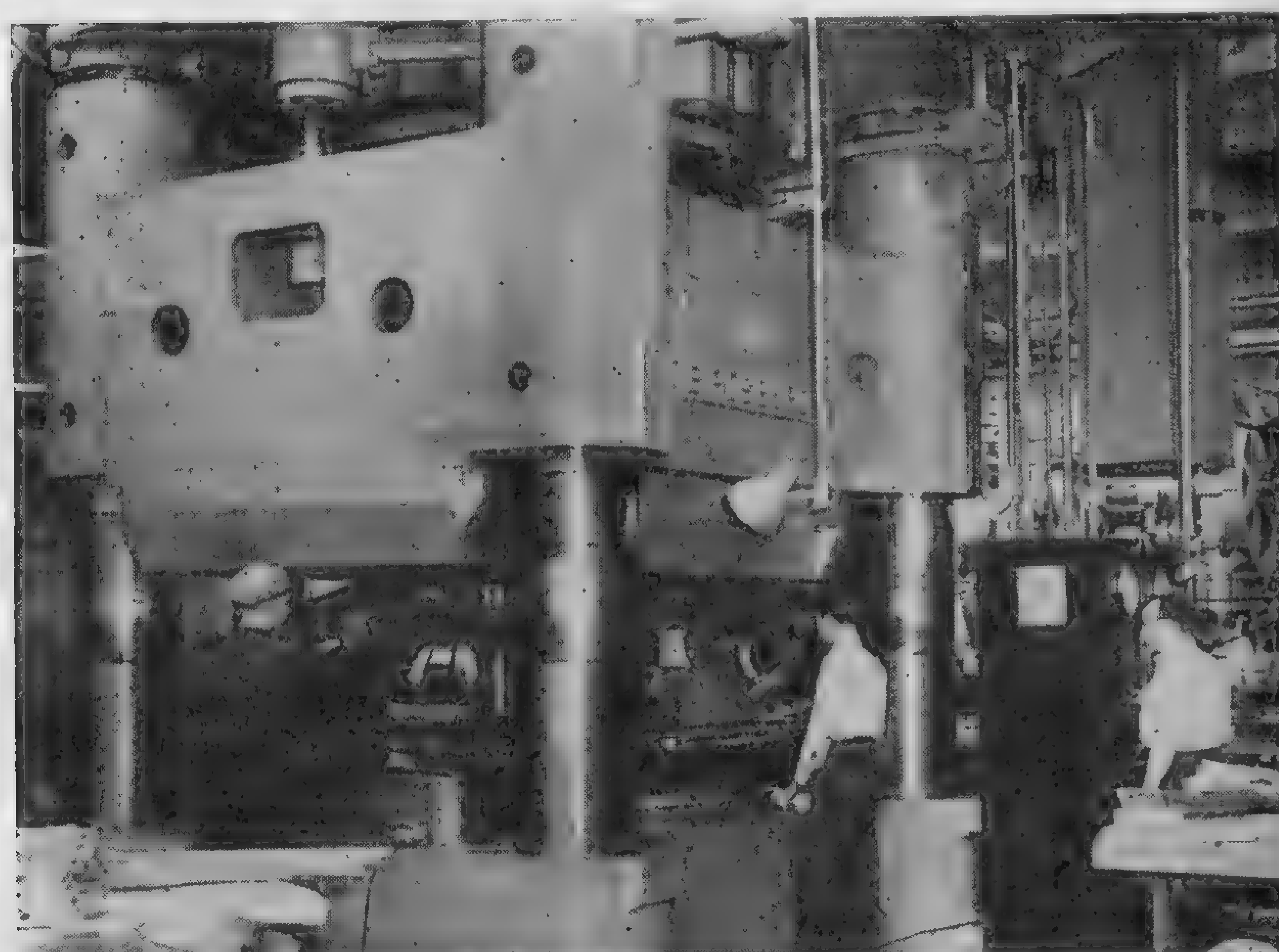


**Fig. 45A. This Huge Hydraulic Press in the Plant of Consolidated Aircraft Corporation Can Exert a Pressure of 4,500 Tons, or the Equivalent Weight of Three U. S. Destroyers**
*Courtesy of Consolidated Aircraft Corporation, San Diego, California*

A method of forming sheet metal parts in a hydraulic power press is that of using a rubber block, which when placed under pressure conforms to the shape of the die, or changes its shape readily and yet returns to its original shape quickly after the pressure is removed. For example, the sheet metal is placed on the rubber block. The die descends and forces the metal to conform to the shape of the die as the sheet is pressed against the rubber block.





This method eliminates one part of the die and so reduces the cost of the tool. It also is possible to manufacture parts to a greater accuracy, which makes for interchangeability, thus eliminating selective assembly, which also reduces costs. The depth and hardness of the rubber block and the pressures used will depend upon the job to be done. However, it has been found by experiment that a rubber block at least 2.5″ thick is necessary, with a hardness of between 50 and 60 durometer.

Fig. 45A, of this section, shows a huge press stamping out or forming shapes from aluminum sheets. As these shapes are worked without heating the material, the process is termed cold working. This cold working has a peculiar effect on the metal in that it becomes strain hardened.

In some cases, where certain aluminum alloys are used, the work hardening or strain hardening process is the only method that can be used to increase the physical properties of the material.

In many cases the metal shape is not completely formed in one pass of the press, and because of strain hardening it often is necessary to anneal the metal between operations so that the metal does not become too hard or brittle.

The method of annealing the metal will be determined by consideration of the material used and the physical qualities required in the finished part.

The heat treatment of aluminum consists of heating the aluminum to a point where recrystallization takes place. The temperature to which the material must be heated will depend upon the material and its work-or strain-hardened condition.

**Riveting.** Metal parts of modern airplanes are jointed by bolts, rivets, or welds. Bolts are used in places where parts have to be taken apart. Rivets and riveted joints and welded joints are permanent joints. Where bolts and nuts are used, the nuts should be cotter-pinned, as it prevents the loosening up of the nut on the bolt through knocking or jarring.

Rivets are perhaps the most widely used means of joining metals, and they come in a variety of sizes and shapes. Fig. 46 shows the different types of rivets used. Some have the regular round head common to most rivets; others are flattened. In joining plates to steel tubes, a hollow rivet is used. Holes for

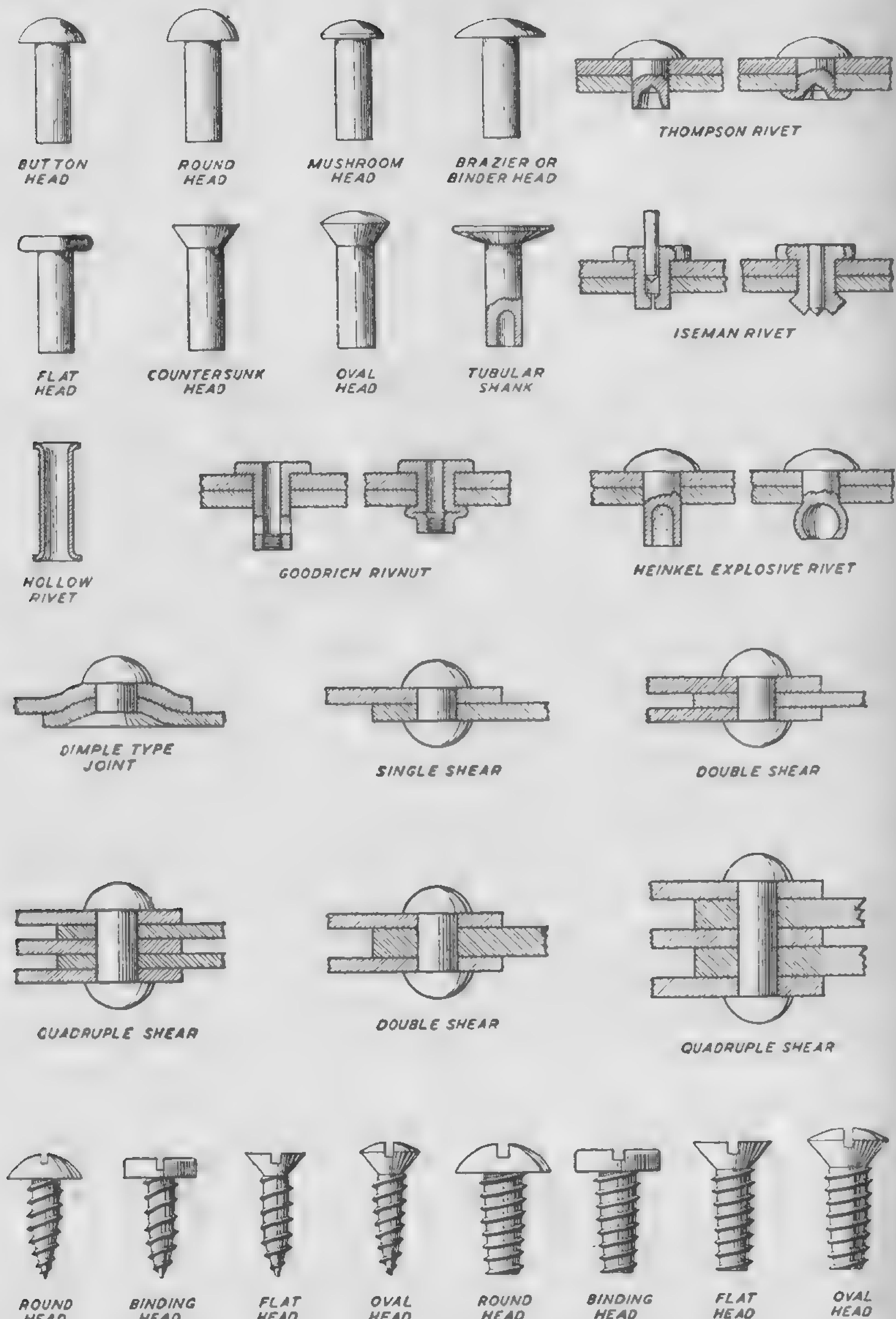



Fig. 46. Types of Rivet Heads and Screws Used in Commercial Aeronautics. The Screws Shown at the Bottom of Fig. 46 Are Parker Kalon Cutting Screws Used for General Repair Work

riveting should be drilled, not punched; this makes for a much more accurate hold. The A17S, 17S, and 53S aluminum alloy rivets should be heat-treated before using. To prevent corrosion,





it is well to dip rivets into a paint preparation to prevent rusting. In ordinary steel work, uneven holes are usually drifted out with a punch. In airplane work, however, small holes should be reamed out to match. As in ordinary riveting work in steel construction, the sheets should be bolted together before and while driving the rivets. The size of the rivet is regulated by the thickness of the plate. The diameter of the rivet should rarely exceed two and one-half to three times the thickness of the sheet and should never be less than the thickness of the thickest plate. It is not

Fig. 47. Automatic Riveting Machine at Bellanca Plant. The Mechanic Is Using an Automatic Riveter in Connection with Instrument Panel and Compartment-Door Riveting Operations. The Machine Shown Punches the Hole for the Rivet when One Pedal Is Depressed; when the Second Pedal Is Pushed Down, the Rivet Is Inserted and Made Secure. This Automatic Riveting Process Is Many Times Faster than Hand Riveting

*Courtesy of Bellanca Aircraft Corporation*

good practice to put rivets in the tension frame. In spacing rivets, three times the nominal rivet diameter is the recommended minimum spacing. The edge distance measured from the center of the hole should be at least one and one-half times the diameter of the rivet.

Because of the difficulty of reaching certain parts of an airplane while in construction, the bucking up of rivets is sometimes extremely difficult. To overcome this trouble, various types of rivets that require no bucking have been developed. In one of these types of rivets—the Heinkle—the back end of the rivet is hollowed out and an explosive is inserted, which is fired by holding a hot iron against the head of the rivet. As a result of the ex-

Fig. 48. In the Manufacture of Lockheed All-Metal Airplanes, Thousands of Aluminum Alloy Rivets Go into Each Plane. Wings, Fuselage, Cowling Parts Are All Riveted, and Each Rivet Is Driven by Hand and Individually Inspected
*Courtesy of Lockheed Aircraft Corporation*

plosion, the inner end of the rivet is expanded and forms a satisfactory head.

In the modern production of airplanes it has been found that a much quicker and better job can be done by using the

Fig. 49. Fabricating Wing Tips In the Plant of Republic Aviation Corporation, Farmingdale, N. Y. The Parts Are Assembled in a Jig (the Outer Frame Work Shown in the Picture) and the Various Sub-assemblies and Surfaces Are Riveted by Men Working in Teams. The Man in the Foreground Is Operating a Rivet Gun, while his Partner, in the Rear, "Bucks Up" the Rivet as It Is Driven by the Gun. In the Background, this Operation Is Reversed
*Courtesy of Republic Aviation Corporation*





automatic, Fig. 47, pneumatic, or squeeze riveter rather than a hand riveter. For large work and also for mass production, the bench riveter is often used. One of the greatest advantages of this machine is that it allows both hands to be free to steady the material, the throttle being operated by a foot treadle.

Much work is also done by a portable pneumatic riveter, Figs. 48 and 49. These are light and are suitable for doing work in limited spaces. The rivet must be bucked with a separate tool.

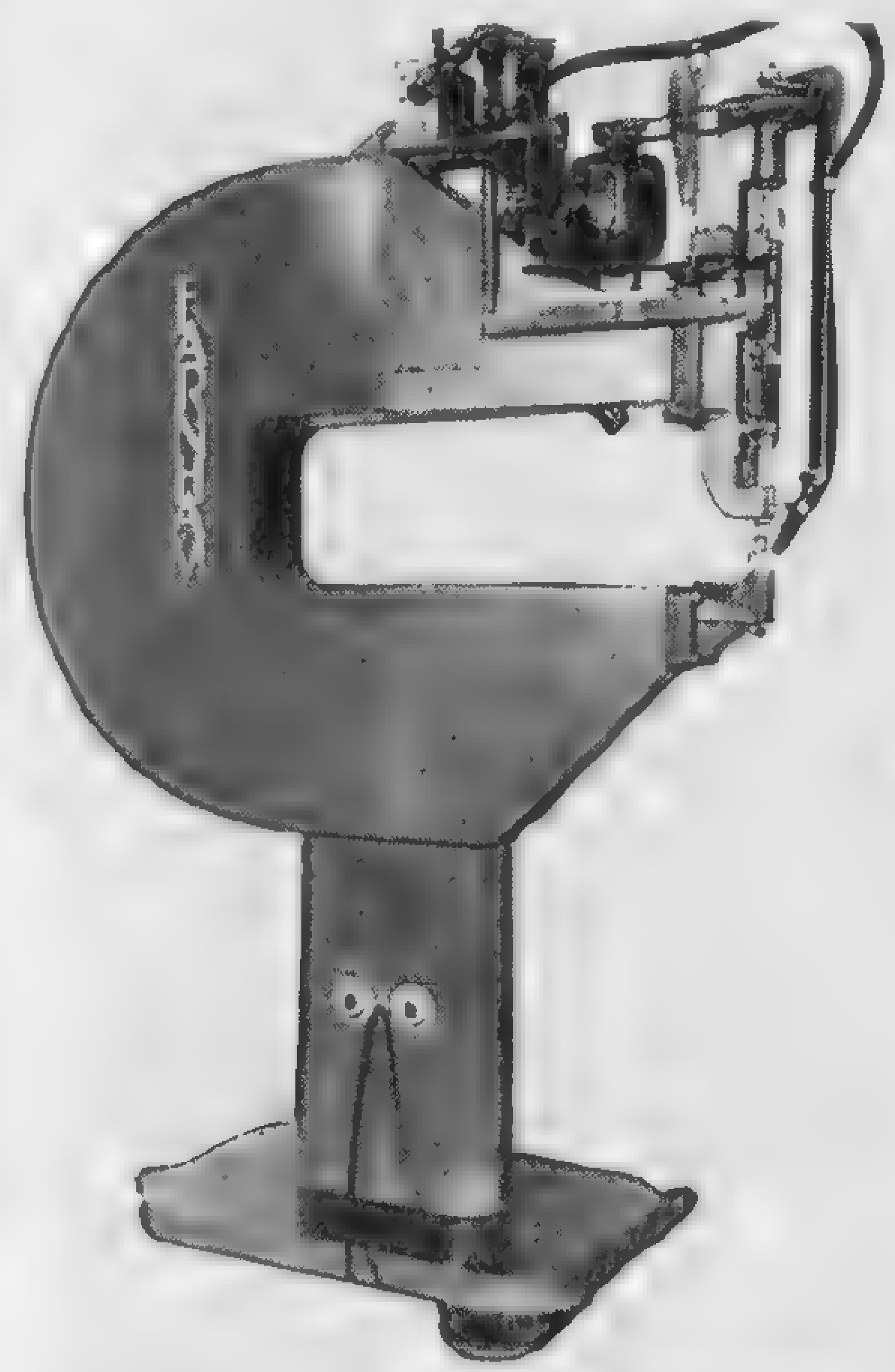


Fig. 50. Farnham Mill Countersinker

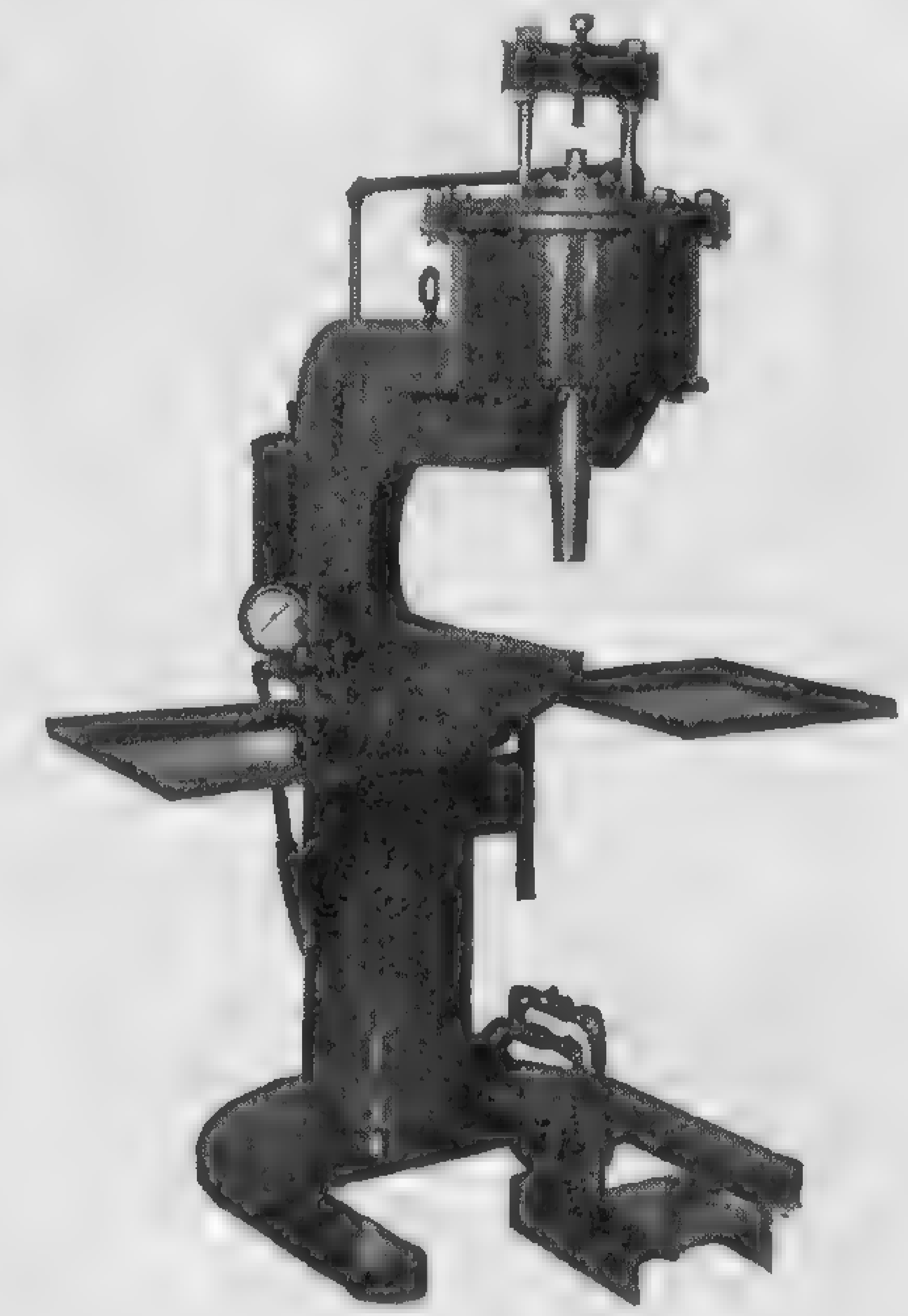


Fig. 51. Farnham Rivet Squeezer

*Courtesy of Farnham Manufacturing Company, Buffalo, N. Y.*

The pneumatic riveter operates on compressed air. When the throttle or trigger is opened, the compressed air causes a plunger in the cylinder to be blown back and forth with great rapidity and force. Rivet headers are supplied with various size cups to make heads in the correct shape.

Where a long line of rivets is to be driven, the sheets have a tendency to buckle. This may be overcome by driving the rivets in a staggered fashion rather than in actual rotation, in the same way that one would tighten up bolts on an auto wheel.

Aerodynamic considerations require the use of flush polished

surfaces for speeds in excess of 300 miles per hour, the demand to date being met chiefly by the use of flush rivets. See Figs. 50 and 51. Dimpled and machined countersunk type rivets must be filed and polished for true aerodynamic cleanness. This is expensive, since individual treatment must usually be given to each depression around the head of each rivet.

**Pneumatic Motors.** Pneumatic motors are used extensively to power rotary pneumatic tools such as routers, drills, sanders, surfacers, grinders, wrenches, etc. The motor, Fig. 52, is operated

Fig. 52. Cutting out Instrument Board Blanks by Means of a Metal Router in the Bellanca Factory. In this Process, Blank Sheets of Metal Are Placed in a Stack and the Router Cuts Them All to an Identical Pattern

*Courtesy of Bellanca Aircraft Corporation*

by compressed air through one, two, or more cylinders quite similar to those in an automobile engine.

**Welding.** The oxyacetylene process is found to be well adapted to joining structural parts of the airplane, such as fuselage, wings, landing gear, control surfaces, engine jackets, exhaust manifolds, tanks, and hard surfacing of engine and tail skids.

The oxyhydrogen process is used for welding aluminum and the non-heat-treatable aluminum alloys in the construction of water, fuel, and oil tanks and other miscellaneous low-stressed parts.

**Arc Welding.** For welding aluminum by the electric arc method, the equipment is similar to that used for other metal





*** Electrode Size and Machine Setting for Aluminum Metallic-Arc Welds**

| Thickness Inch | Electrode Diameter Inch | Amperes | Rods per Pound |
|---|---|---|---|
| 0.064 | 1/8 | 45-55 | 32 |
| 0.081 | 1/8 | 55-65 | 32 |
| 0.102 | 1/8 | 65-75 | 32 |
| 0.125 | 1/8 | 75-85 | 32 |
| 5/32 | 1/8 or 5/32 | 85-100 | 32-23 |
| 3/16 | 5/32 | 100-125 | 23 |
| 1/4 | 5/32 or 3/16 | 125-175 | 23-17 |
| 5/16 | 3/16 | 175-225 | 17 |
| 3/8 | 1/4 | 225-300 | 10.5 |

* Courtesy of Aluminum Company of America.

welded by the electric arc. The gage of the metal being welded controls the capacity needed by the machine. Arc welding, while it causes less distortion than gas welding, is not suitable for aluminum sheets less than 1/16″ thick.

**Welding Electrodes.** The electrodes should be of the flux-coated type.

The following table shows the size of the electrode and output of the machine for metallic-arc welds of aluminum.

**Flux.** A flux is just as necessary for arc welding as it is for torch welding. For use on aluminum, the proper flux is one that melts just below the melting point of aluminum. It should flow freely; and to quickly remove the oxide, the flux should not mix with the aluminum but come to the surface of the molten metal. The flux should be stable under the temperature of the arc. When the flux is placed on the electrode and dries, it should not chip off, but bind well together.

The flux is made into a paste and the electrodes dipped in the paste and allowed to dry.

**Spot Welding.** The principal field for spot welding is the fabrication of structural parts, containers, flooring, and other details made from thin sheets, extrusions, and rolled or drawn sections from corrosion-resistant steel and aluminum alloys.

The development and application of spot welding was first undertaken because of the possibility of reducing production costs.

Fig. 53. Spot Welding Operation on Dural Instrument Board Assembly in Bellanca Factory. The Spot Welding Process Is Much Faster than Riveting, yet It Provides Strong Joints
*Courtesy of Bellanca Aircraft Corporation*

Experience has shown that parts which are easily riveted are also easily welded, while parts which are difficult to rivet are also difficult and even impossible to weld. However, in some instances, welding is economically practiced where riveting is not. See Figs. 53 and 54. In general, it may be stated that the cost per weld will be from 1/8 to 1/10 of the cost per rivet for any design.

To carry out spot welding to the greatest advantage requires that the major or special units be broken down into a number of smaller, easily handled subassemblies. These subassemblies should take the form of panels, consisting of skin and stiffener or skin and former combinations. In practice, structural units in panels, from 14 feet in length, have been easily handled and welded. Such panels should be flat or have a relatively generous curvature for the most economical welding.

Experience has shown that the breakdown of structural units, as forced by the requirements of welding equipment, has resulted in the more extensive use of already formed parts. The use of more simple and easily constructed assembly systems, and the shifting of a number of assembly operations from the floor to the bench has also permitted reduction in production costs.





In assembling units for welding purposes, it is necessary to drill a few holes for rivets or screws at critical points. These merely serve to hold the various parts in their proper relationship, one to the other, for welding.

Flush rivets are seldom actually flush and therefore the task of filing them is even more difficult. Spot welding will provide an absolutely flush surface without requiring the extensive use of filing materials. This is accomplished by using a flat welding electrode on the side where the flat surface is desired. No reduction in weld strength may be noted when one flat electrode is used. In case where the piece has considerable curvature, as on the fuselage or on nacelles, a small flap or crater is made by the flat tip. In this case, one of the highly pigmented enamels may be sprayed on to fill in the craters after the primer coat has been applied.

Where welded structural parts are subjected to compressive loads, it is necessary to subject the parts to work hardening, so that their yield strength may be equal to that of the parent material. This may be accomplished by hammering or rolling the line of weld, the latter being the more satisfactory of the two methods, since it is faster and gives more reliable results. A

Fig. 54. Better Quality of Spot and Seam Welds Has Resulted from the Installation of Two New Resistance Welding Machines in the Factory of Lockheed Aircraft Corporation, Burbank, California

degree of cold working may be measured by taking Rockwell readings, at the center of the spot, before and after rolling. The amount of pressure required for a properly cold-worked weld must be definitely determined. It depends upon the diameter and the width of the rollers used, but will not vary with changes in the gage. Both rollers should have approximately the same diameter and be as small as possible. Any aluminum alloys, in any reasonable number of sheets may be satisfactorily welded. Preference should usually be given to the Alclad materials because of the greater number of welds which can be made without dressing the tips. Extrusions of any alloys may be welded to sheet stocks, unless prohibited by detailed specifications. Spot welding cannot be done properly through anodized parts, or wet or dry paint, or primer.

Spot welding should not be called for on assemblies to which steel parts must be attached prior to welding, or when the assemblies must be anodized. Because of the relatively low strength of spot welds in tension, conditions which will impose a severe tension load in welds should be avoided. It is desirable to tie down each end of a row of spots with a rivet, especially in the thinner materials. A rivet should be used whenever an extra thickness of metal is picked up and at the ends of stiffening elements. Parts should not be heat treated after welding. Heat treatment will not improve the weld strength.

**Welding of Stainless Steel.** The best known and most widely used of the stainless steel alloys is "18-18", which is obtainable in any form. It can be fabricated in practically any way that other metals can, but not so easily because of its stiffness. It may be stamped, punched, forged, cast, machined, and spun. It may be soldered with either lead or silver solder, but it should not be brazed. It may be spot welded, shot welded, or flash welded. Ordinarily speaking, stainless steel gas-welds about the same as mild carbon steel, with a few important exceptions.

A reducing or slightly carbonizing flame with little oxygen must be used to keep from burning the metals, and the weld must be carried along a lot faster than with ordinary steel. This is especially true with the light gages that are used in aircraft construction. Stainless steel warps easily under effects of heat, and





Fig. 55. The Plastic Plane Passes Its First Flying Tests at Van Nuys, California
*Courtesy of Acme Photo*

allowance has to be made for this if the finished weld is to conform to true standards.

Stainless steels may be electrically welded by any of the recognized methods. In electric arc welding, the current is set about half the value used for corresponding sizes in mild carbon steels. One of the first airplanes to use all stainless steel construction, fabricated by the shot and spot welding, is the Fleet Wings 5*F Amphibian Seabird. The hull is semi-monocoque designed. The bulkheads and frames consist of bulb angles and Wagner webs, shot welded to longitudinal fingers, and the stainless steel shins. All joints are shot welded. Wing and tail are of stainless steel

Fig. 56. Center Sections of Martin Bomber, Model 167-F, in Assembly Line
*Courtesy of The Glenn L. Martin Company, Baltimore, Maryland*

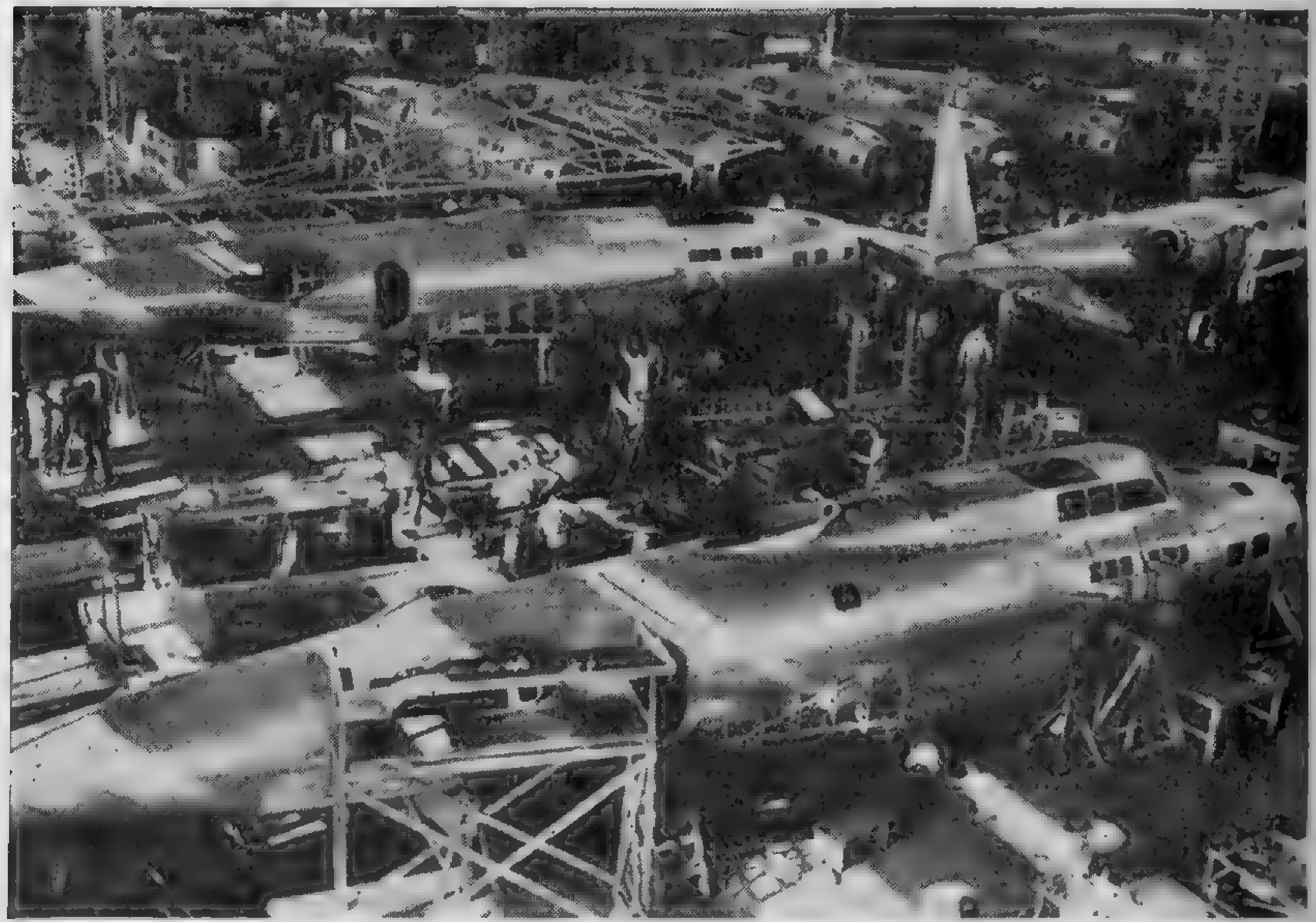


Fig. 57. Showing a Number of the Boeing B-17b Bomber Bodies. The Body in the Center of the Picture Is Being Lowered by Overhead Cranes to Its Place on the Assembly Floor
*Courtesy of Boeing Aircraft Company, Seattle, Washington*

Fig. 58. In the Plant of the Douglas Aircraft Co., Inc.
*Courtesy of the Douglas Aircraft Co., Inc.*





structure, fabric covered. Two box type spars are used with intermediate ribs and built-up rag strips. The flaps also are of stainless steel.

At this time it is well to mention the molded plastic type of construction for wings and fuselages. Plastics are well along toward general use for full-piece wings and fuselages. Molded units are used, not only for surface material, but the stronger material is molded for stiffener members, eliminating the labor of drilling, riveting and fitting. A plastic plane is shown in Fig. 55.

## AIRPLANE WIRE WORK

Strict attention should be paid to the condition of the wire work on an airplane at all times. All wires should be inspected after each flight, and if you find any piece of stranded flexible cable with broken strands, kinks or distortions of any kind you should replace it at once. Special attention should be given the control cables, especially at points where they pass around pulleys.

In working with wire, adhere to the following rules:

1. Never straighten out a kink.
2. Measure accurately in replacing old wires.
3. Hard-drawn steel wire should never be bent more than once; if the surface is cut or marred, it should not be used.
4. Before cutting a cable, wrap it with soft iron wire or solder it on either side of the place where it is to be cut. This prevents the strands from raveling.
5. Practice working with wire until your work is perfect.
6. Never pass work as "good-enough," make it right.

Few tools are required for wire working, but these should be of good quality and kept in good condition at all times. This is particularly true of the soldering iron. The following list of equipment is necessary:

1 Blow torch
1 Heavy soldering iron
1 File, (coarse on one side and fine on the other)
1 Cold chisel
1 Pair of pliers (round nose)
1 Pair of heavy cutters
1 Steel rule

The soldering iron should be kept "well-tinned" so that the work done with it will be clean and strong. A soldering iron is tinned in the following manner: First, heat it hot enough so that after it has been filed clean it will still retain sufficient heat to be tinned thoroughly without reheating. Apply a paste flux, while turning the iron over in a puddle of solder, until it has been thoroughly coated. Solder will not stick to bare copper, so that if a drop of solder will stick to the iron after it has been coated with solder, or tinned as it is more commonly spoken of, the iron is satisfactory for use. The "tinning" will burn off if the iron is heated too hot; if this occurs, repeat the above process.

The blowtorch should never be more than two-thirds full. To operate, first open the valve and pump up the pressure slightly to allow some of the gasoline to flow into the cup. Close the valve and light the gasoline. This will heat the nozzle, which when properly heated helps to carburet the mixture of gas and air. When the lighted gasoline in the cup is nearly burned out, open the valve slowly, after you have pumped up sufficient pressure in the tank. When the proper blue flame has been reached, allow the valve setting to remain as is.

Cable wire is made of selected steel of the best grade. Four kinds or types of wires are used for airplane work:

1. Flexible hard-stranded cable
2. Extra-flexible cable
3. Hard-drawn wire
4. Wrapping wire

Flexible hard-stranded cable is used for the landing and flying wires, and for bracing wire in the engine section. For control purposes, an extra-flexible cable is used. In making repairs care must be taken not to use hard-stranded cable for control purposes, not only because it is too hard, but because it frays badly and quickly where it passes over pulleys.

In sections that are not easily accessible for adjustment, such as the inside wing bracing, hard-drawn wire is used. This type of wire will stretch very little once it has been put into place.

Wire used for wrapping is usually copper, brass, or tinned soft steel wire.





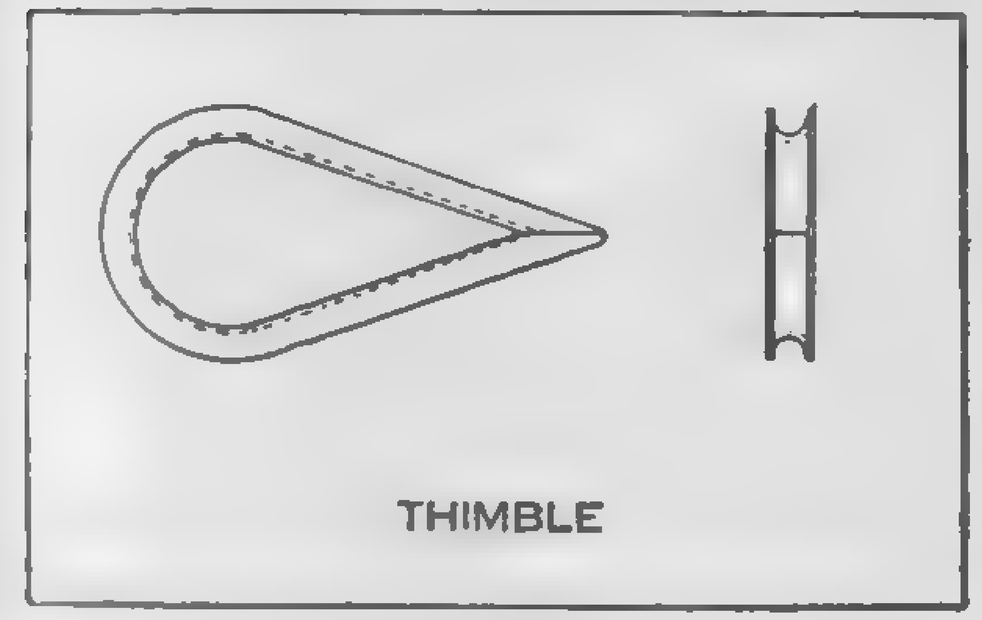


Fig. 59

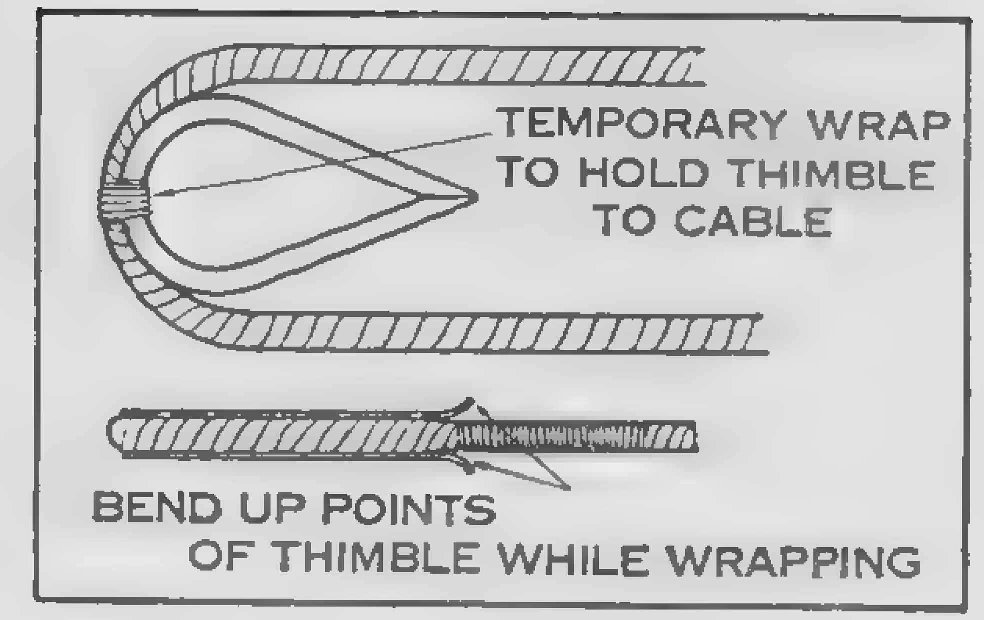


Fig. 60

When an old cable is to be replaced, accurate measurement is absolutely essential. The new cable should be of a length which will insure all threads at each end of the turnbuckle being covered. See Fig. 76.

In case you are replacing a cable at the end of which it is necessary to use a thimble (Fig. 59) a loop must be made to fit around the thimble. This loop should be made in the following manner: The cable should be bent tightly around the thimble and fastened temporarily as shown in Fig. 60. A soft wire is used for this fastening. Sufficient overlap in the cable should be left to permit holding it in a vice for soldering purposes. After the first temporary wrapping has been made, add another at the point where the two pieces of wire come together so that the thimble will not drop out.

After this has been done, clamp the wires tightly in a vice, and solder the two wires together. See Figs. 61 and 62. Do not use too much solder, as it is only necessary to solder them sufficiently to hold them together for wrapping. In order to streamline the short end of the cable, fray it slightly and pick out one strand at a time and cut it off, staggering the cuts.

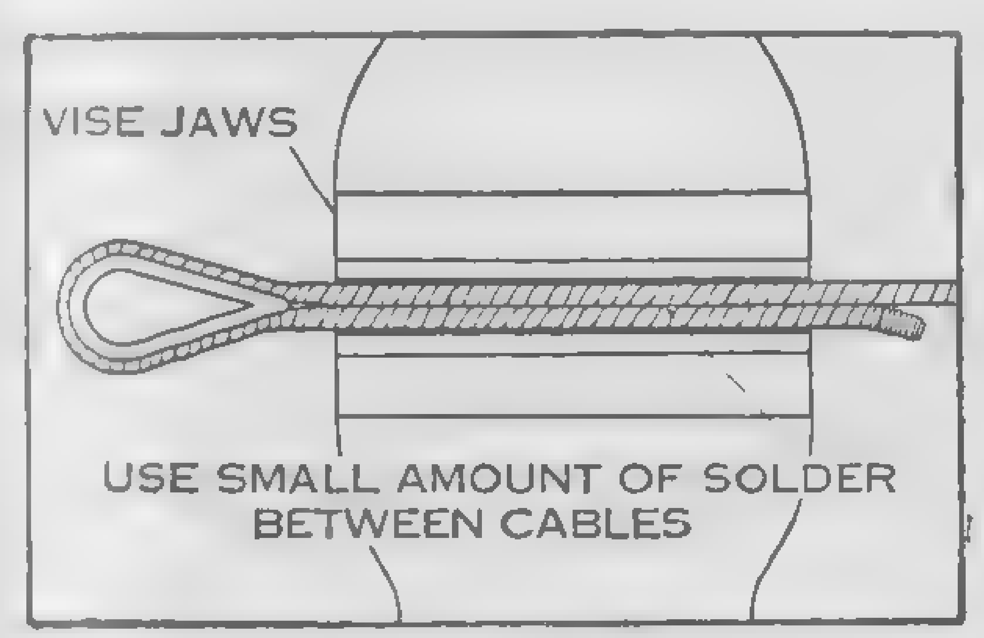


Fig. 61

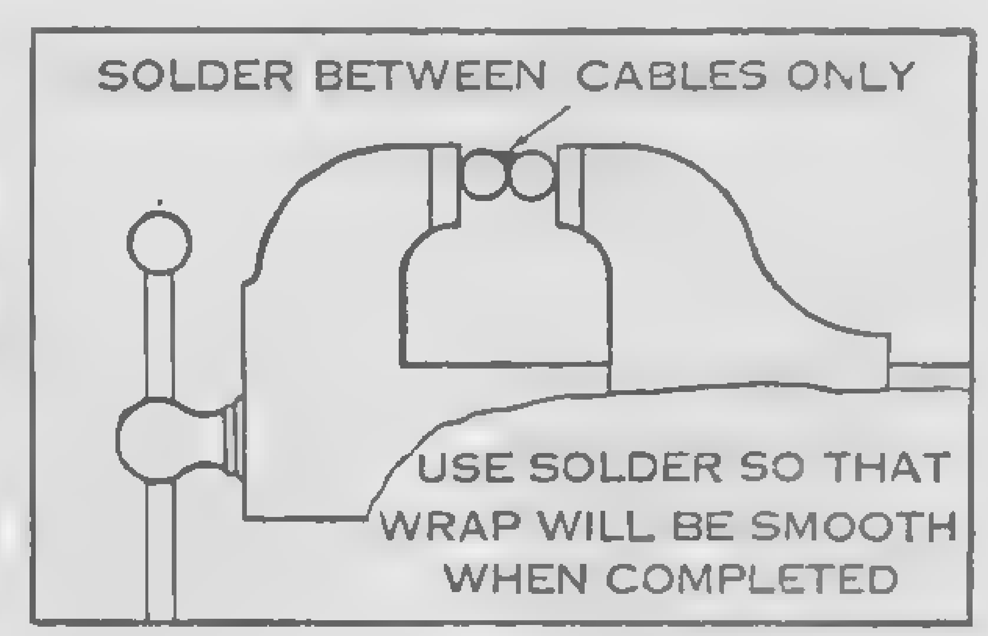


Fig. 62

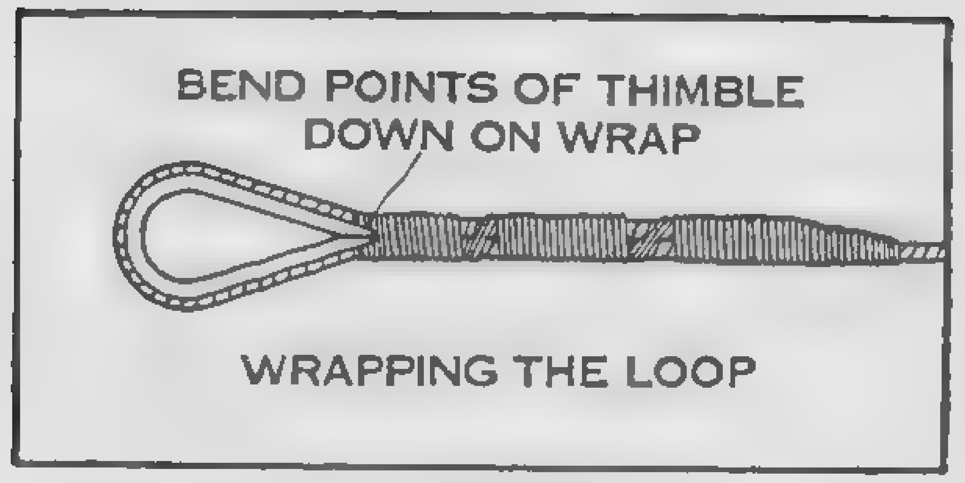



Fig. 63

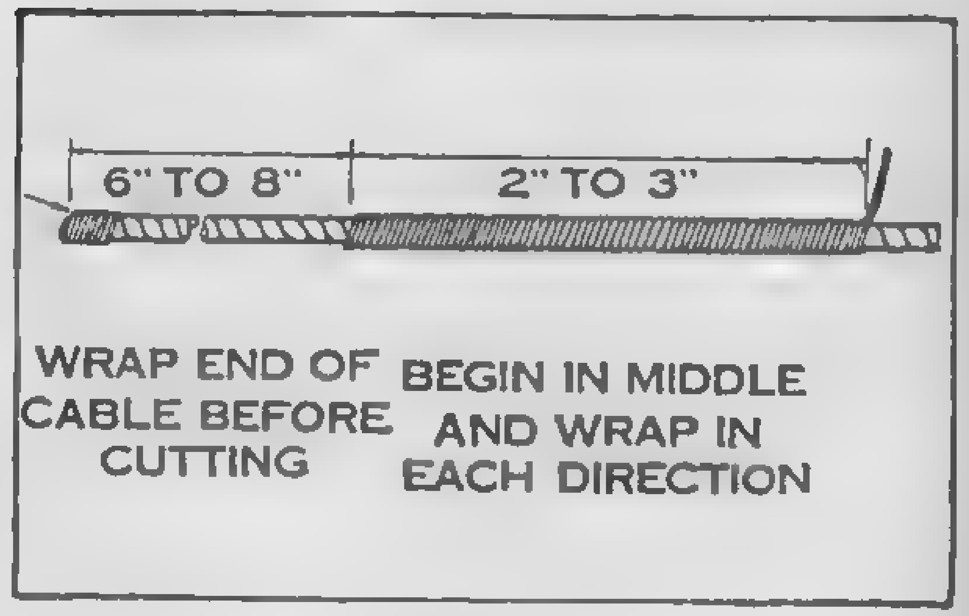



Fig. 64

Next take the wrapping wire (soft-wire) pass one end through the thimble and get both ends even. Then wrap the wire double in the manner shown in Fig. 63. After the wrapping has been completed, solder the entire joint, making absolutely sure that the solder penetrates the entire wrapping.

If it is necessary to make an emergency repair, and a thimble is not available, a loop can be made in the manner illustrated in Figs. 64, 65 and 66. The same procedure should be followed in regard to soldering as has been previously described.

Another form of wire work, the necessity for which exists around an airport, is what is called the "ferrule." This is made from the same sized wire which it is to be used on, and is made of hard-drawn wire. Before a satisfactory job can be done, considerable practice is required.

First a loop must be made at the end of the wire on which the ferrule is to be used. The eye of this loop is made with round nose pliers, or by bending it around two bolts placed in a vice. The bolts should of course, be of equal diameter. The manner of doing this is made quite clear by reference to Figs. 67, 68, 69 and 70.

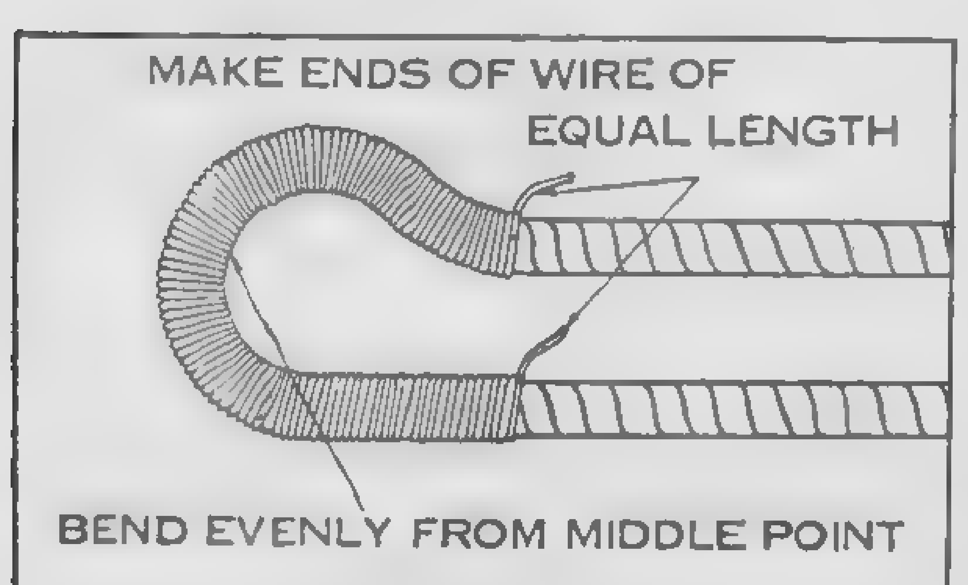



Fig. 65

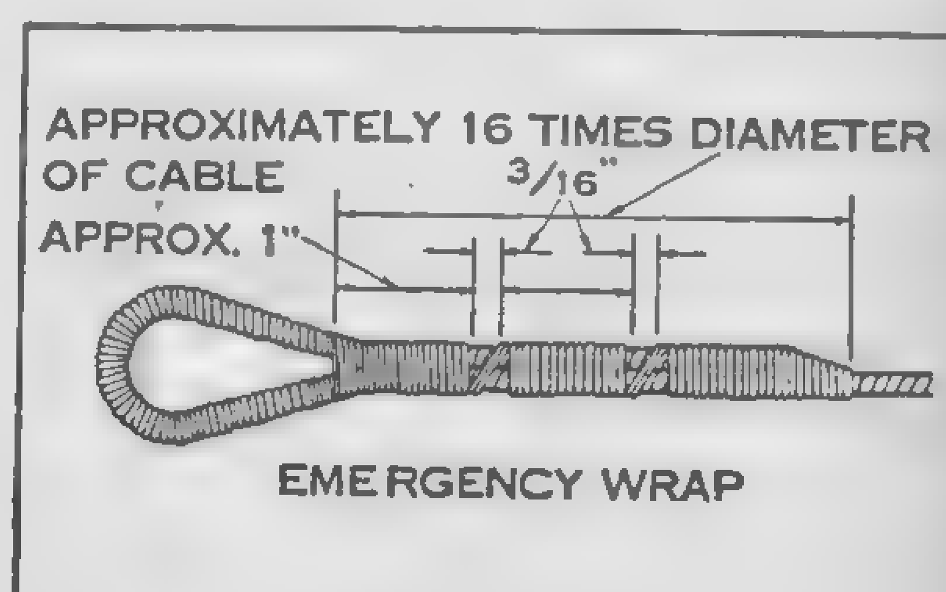



Fig. 66





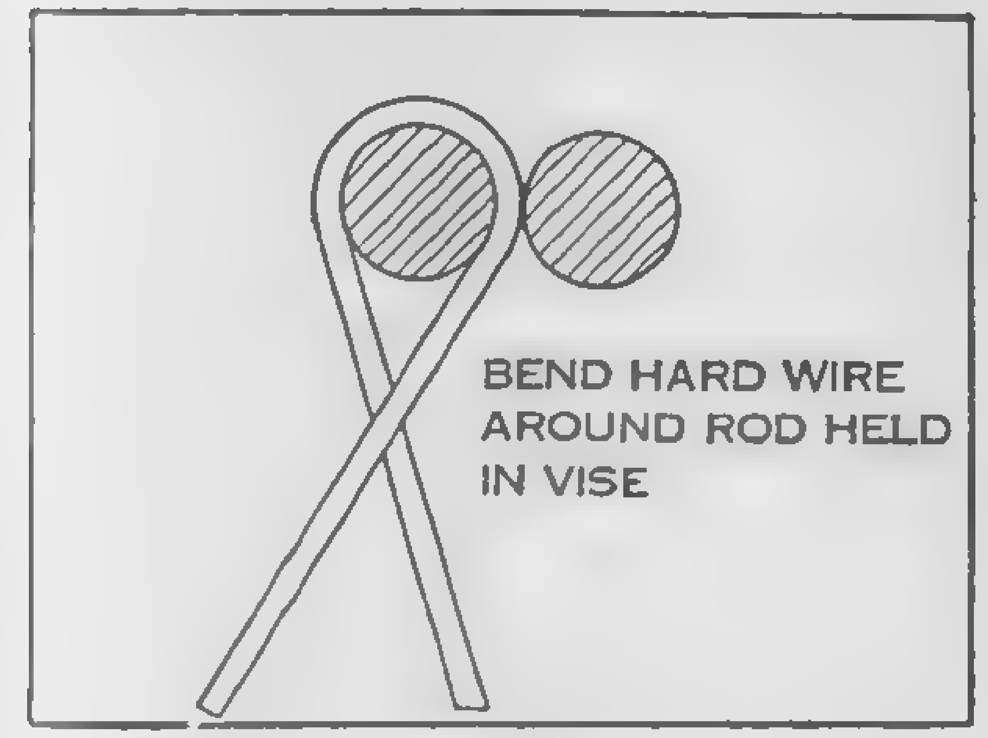



Fig. 67

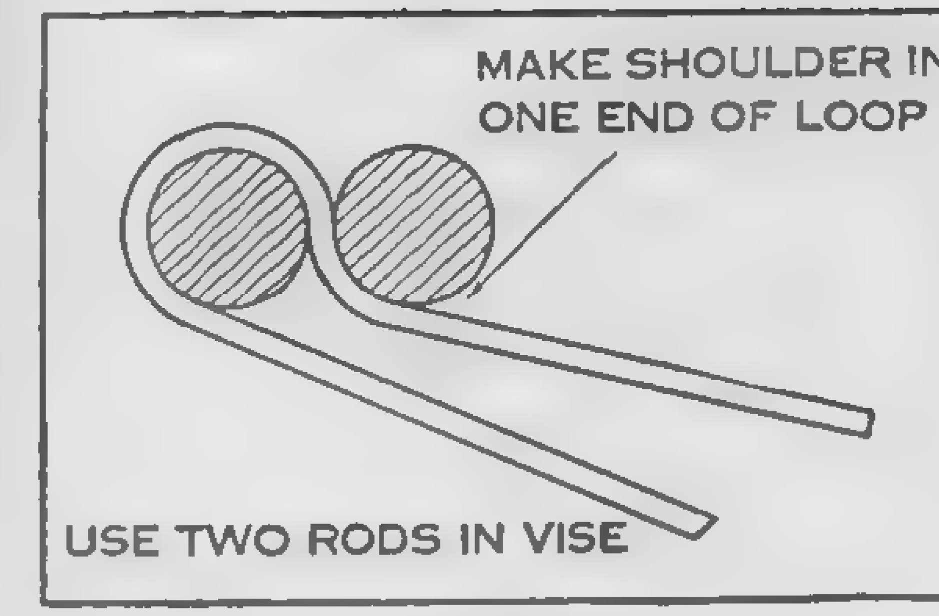



Fig. 68

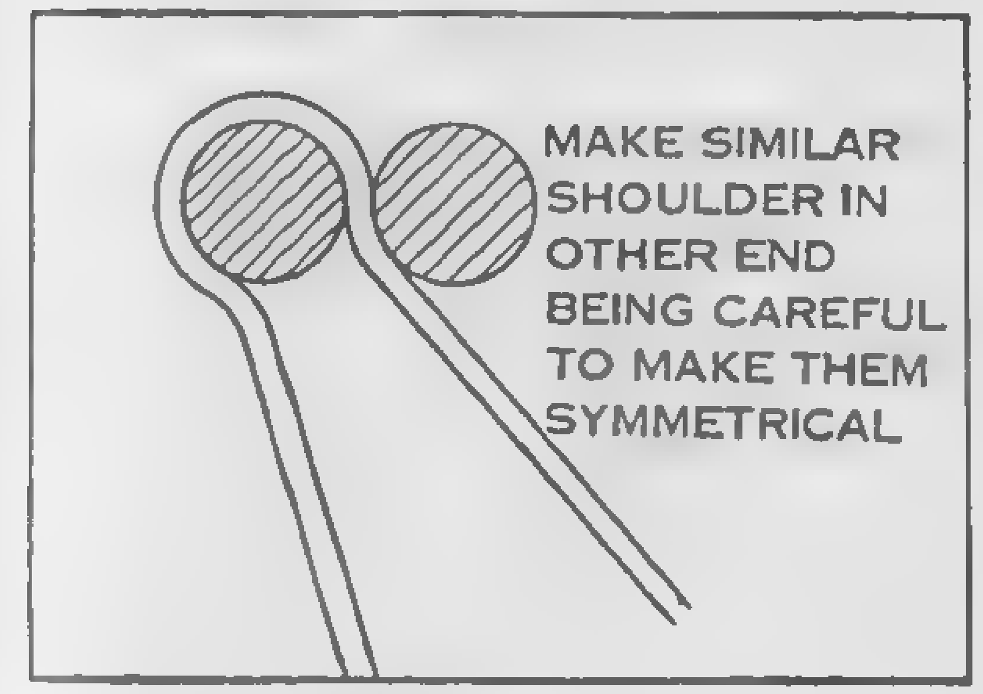



Fig. 69

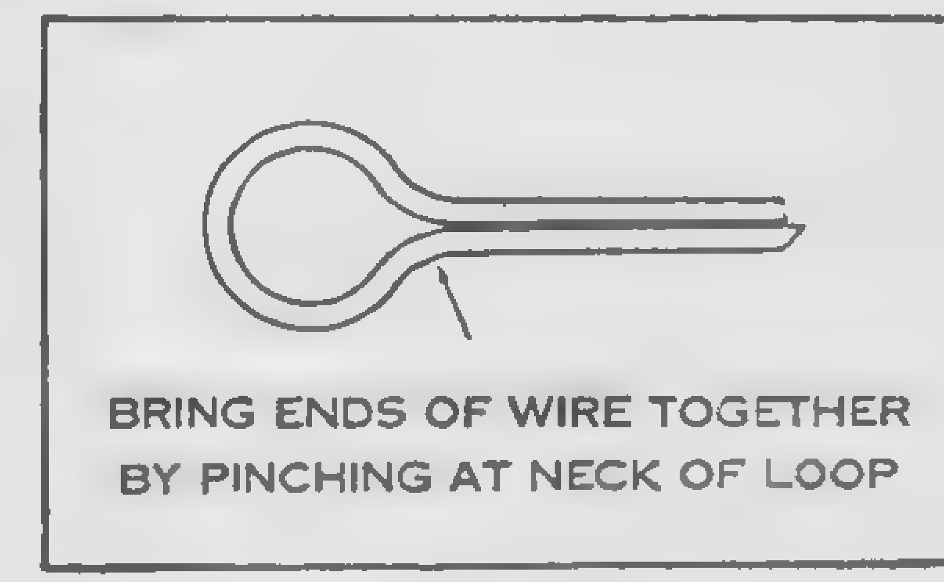



Fig. 70

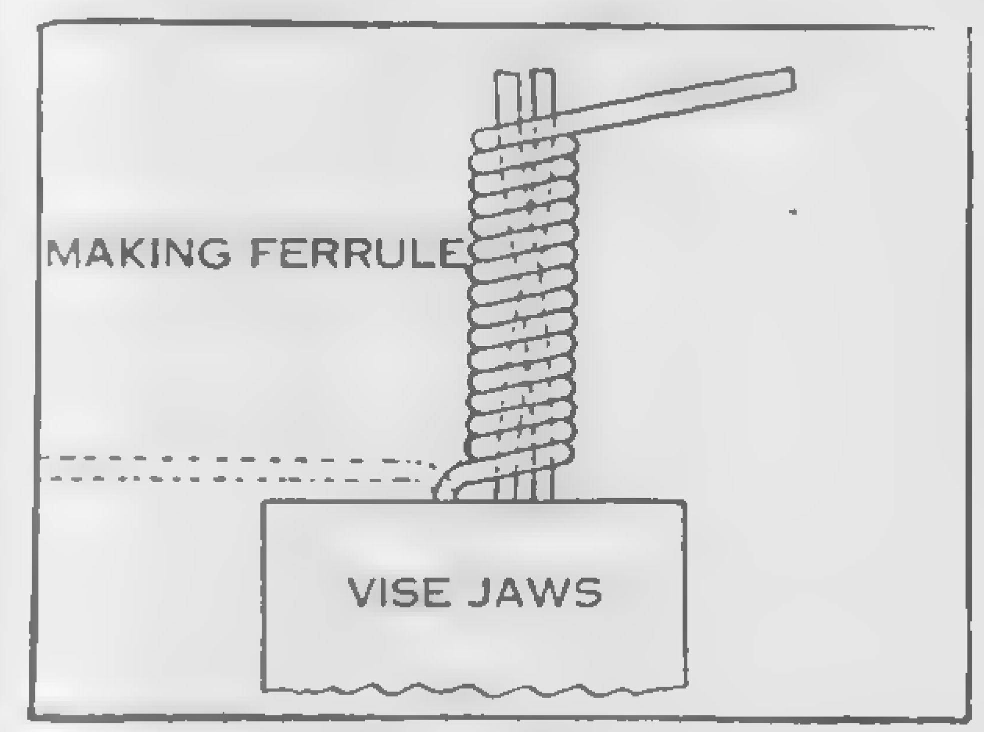



Fig. 71

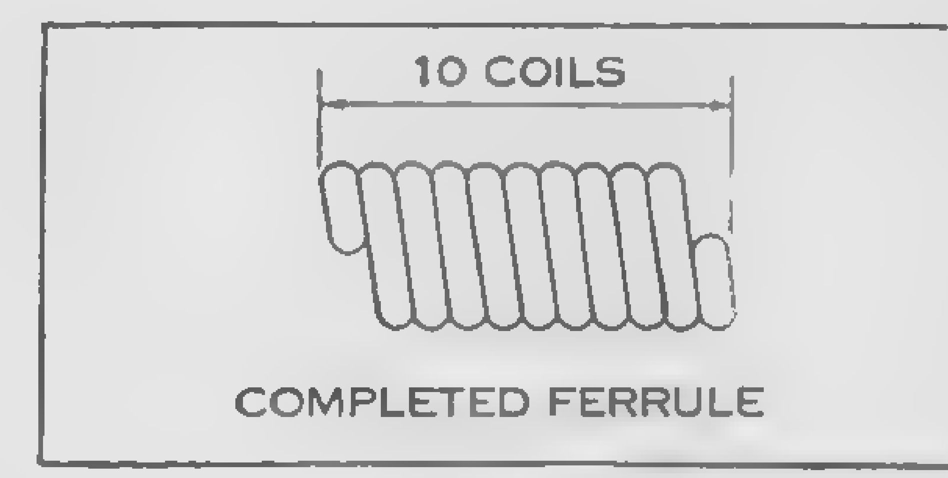



Fig. 72

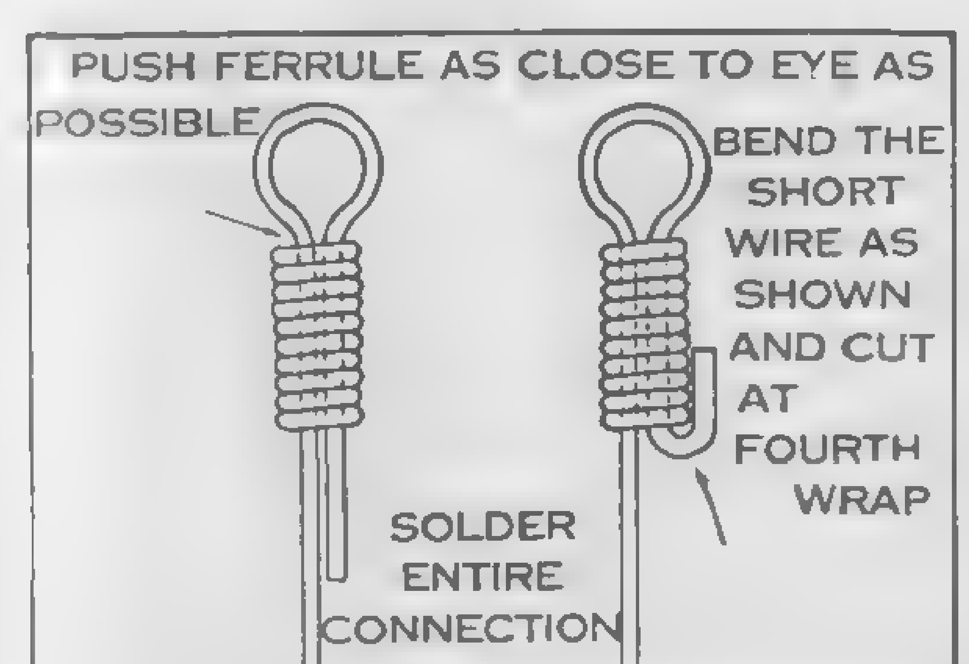



Fig. 73

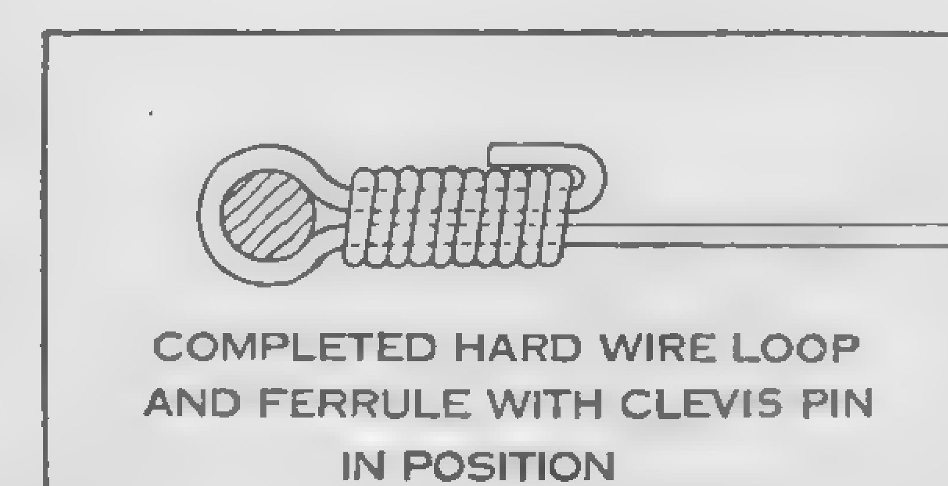



Fig. 74

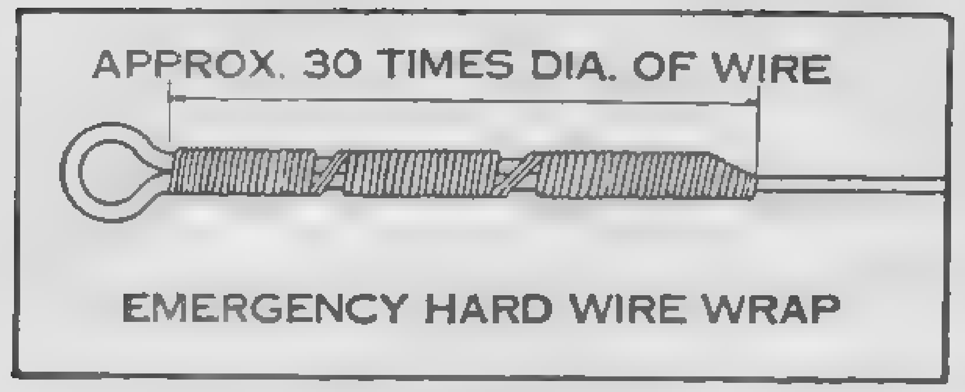



Fig. 75

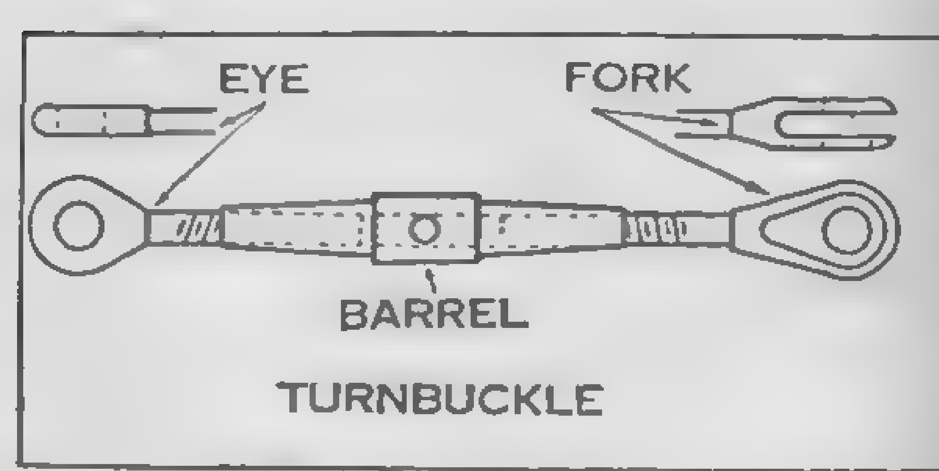



Fig. 76. When Turnbuckle Is in Place, All Threads Should Be Covered

To make the ferrule, place two short pieces of wire in the vice together with the wire from which the ferrule is to be made. These wires should all be of the same gage or thickness. The manner of placing these wires is shown in Fig. 71. It will be noted from this illustration that the wire which is to make the ferrule is first bent down practically even with the face of the vice. The two short wires are given one complete twist in the direction the wrap is to be made. This is done to do away with the natural twist which occurs in the ferrule as it is being wound. Make ten or more complete wraps of the long wire, making sure that you use the same tension in each of the wraps. File both ends of the ferrule so that they will be entirely smooth. Take the completed ferrule off the short wires, and slip it onto the wire loop, Fig. 73, fitting it snuggly against the shoulder of the eye. Bend the short end of the wire forming the eye or loop, up along the ferrule and cut off four wraps from the end, Fig. 73. The ferrule should then be soldered in the manner previously described for loops.

An emergency field wrap can also be made with hard wire in the manner shown in Fig. 75. This should be soldered in the same way as other wraps.

Fig. 76 shows a turnbuckle, which is used to secure tension in cable and bracing wires. The barrel is made of bronze and the shanks or couplings are made of nickel steel. These fit into the

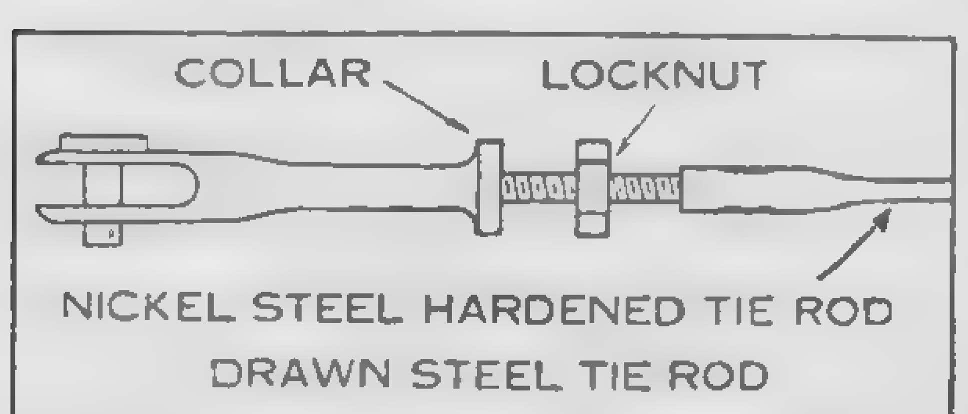



Fig. 77. Tie Rods Are Frequently Used Instead of Cables for Bracing

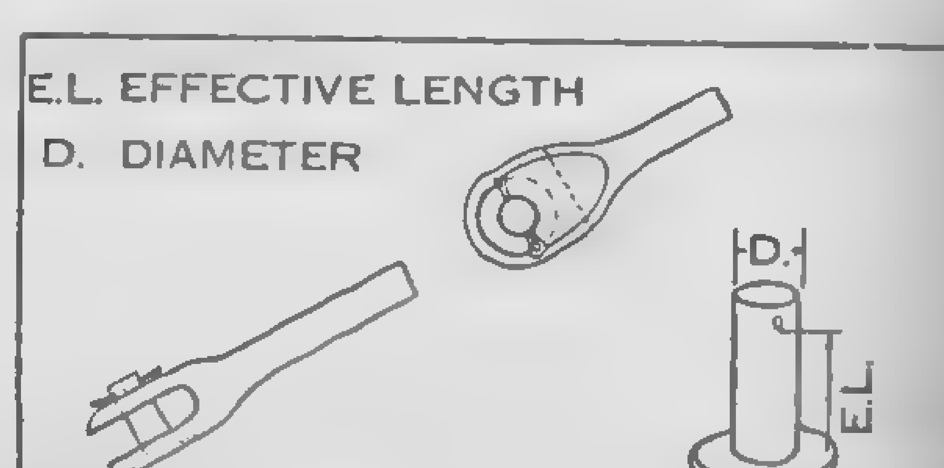
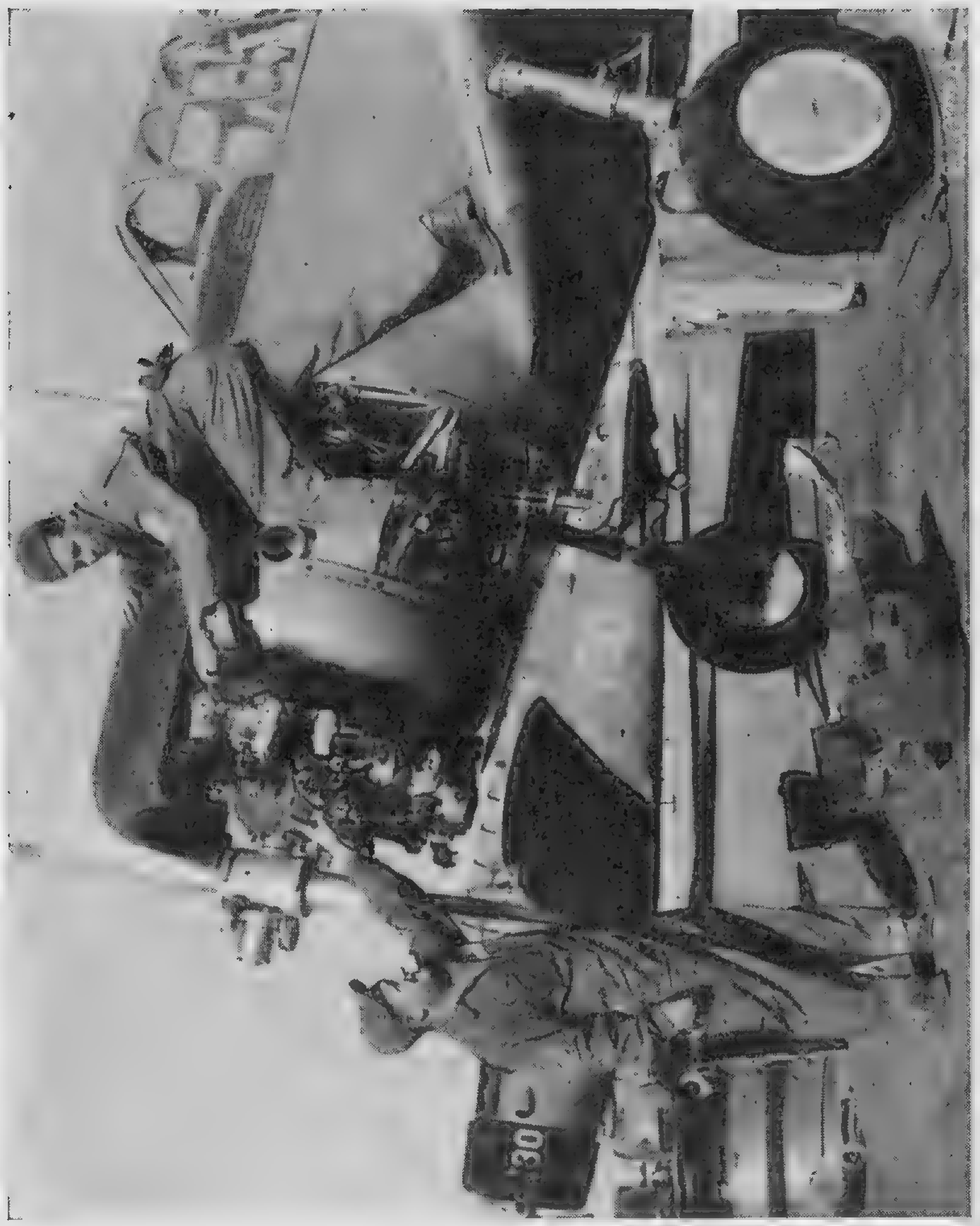



Fig. 78. Method for Measuring the Tie Rod, Clevis and Clevis Pin





hollow portion of the barrel by means of threads. One shank has a right-handed thread, while the opposite one has a left-handed thread. In this manner, by turning the barrel, both ends are brought up evenly. In conclusion, your attention is again directed to the importance of measuring all cables accurately. If it is an old cable that is being replaced, and you do not have access to a drawing which will tell you the exact length of the cable, remember that the old cable has been stretched somewhat through use, and that the new cable should therefore be slightly shorter than the old one. Also, always remember to oil all new control cables with a clean oil, to keep them from rusting. Remember too that in addition to doing your work right, the most important thing is that it be done neatly.



CHECKING A FEW CRITICAL FEATURES OF A BT-13A ENGINE
*Official Photograph, U. S. Army Air Forces*

# CABLE SPLICING

## DESCRIPTION OF CABLES

The cables most commonly used on airplanes range in size from $\frac{1}{16}''$ to $\frac{3}{16}''$. All cables used on airplanes are made of high-grade steel wire. Each cable consists of seven different strands, with nineteen wires in each strand. The seven strands are rolled like a rope. This is called extra-flexible cable.

Cables $\frac{3}{32}''$ and under are usually made with seven strands, seven wires in each strand. This is called semi-flexible cable.

Each cable has a core strand. It is one of the seven strands and runs through the center of the cable. It is a straight strand around which the other strands are wrapped, making them curved.

The new cables are covered with a tinning or galvanized coating to help prevent rust.

## CARE OF CABLES

The care of cables is very important, as the safety of an airplane depends upon the care and maintenance of them.

Cables are subject to rust through atmospheric conditions which vary in different parts of the country. Extra precautions must be taken with the cables of an airplane flying close to or over salt water. Salt water has a tendency to make cables rust and fray more quickly than would be the case in flying over inland country where there is no salt in the air.

To prevent the fast-rusting of cables in salt atmospheric conditions, the cable, after it has been spliced and made ready to install, is placed in a solution of beeswax, Prussian blue and Lionoil. Sufficient solution must be used to completely cover all cables that are to be coated at one time. The solution must be hot but should not be brought to the boiling point. Leave the cables in the solution for thirty minutes so that each strand will be covered. Hang the cables up to dry and allow excess solution to drip off. This solution may be used indefinitely. Even with these precautions the cables must be watched very closely for frayed strands.

A new kind of cable is now being used when flying over salt water. It is made in the usual way, but is constructed of stainless steel.

Under ordinary conditions, when flying over land away from salt atmospheric conditions, use a solution of Lionoil and Prussian blue. Put the cables in the solution as before. Watch and see that the solution does not boil.

Every precaution must be taken with cables so as not to damage any of the small wires.

## INSPECTION OF CABLES

When inspecting cables, use a soft cloth or the hand to rub over the wires to find frayed places. If frayed at any point, the cloth will catch on the frayed part. Frayed places are usually found around pulleys, leather guides, and through fair leads. If one frayed place is found in the cable, it *must be replaced.* If not replaced, the cable may become jammed and cause an accident. If a frayed place is found in the cable, give it a slight twist and usually other broken strands will be found. One frayed wire causes the cable to lose the strength it must have for safety.

## TOOLS AND MATERIALS

The tools needed for splicing are: rawhide mallet, Fig. 1; cable splicing clamp, Fig. 2; pair of high-grade wire cutters or diagonals, Fig. 3; marline spike, Fig. 4; good pair of pliers, Fig. 5; cold chisel, Fig. 6; hammer, Fig. 7; 50-foot steel tape measure, Fig. 8; and block of hard wood, 4″x4″, Fig. 9.

The cable splicing clamp and marline spike can be made. The wire cutters or diagonals must be good, otherwise they will not stand the strain.

The marline spike is rather dangerous in that the wires may be cut by it if care is not taken. Also, if the spike should slip it might go through the hand very easily.

The following materials are needed: the right size and length of cable, No. 6 waxed linen cord, thimbles, Fig. 10, and shellac.

A non-acid flux solder must always be used. Never use solder with an acid core, as acid eats through the wires immediately.





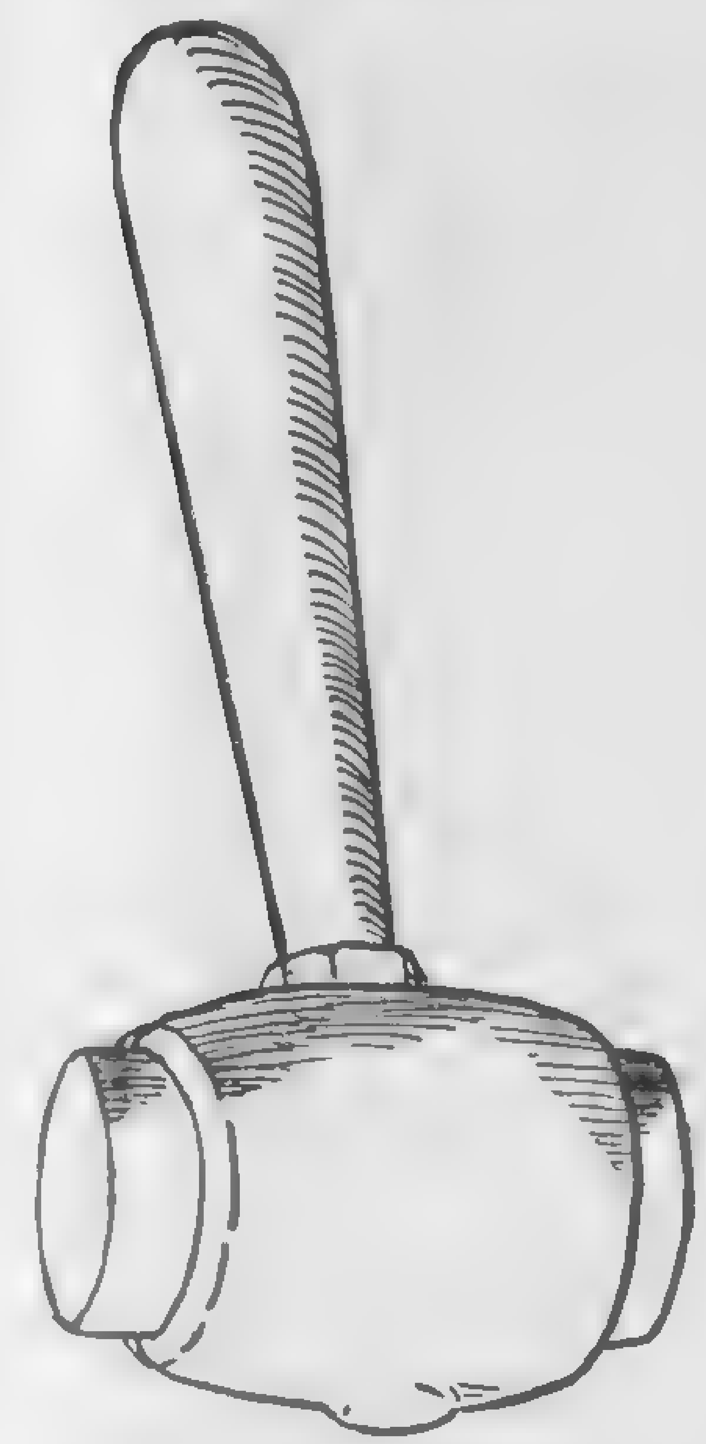


Fig. 1. Rawhide Mallet

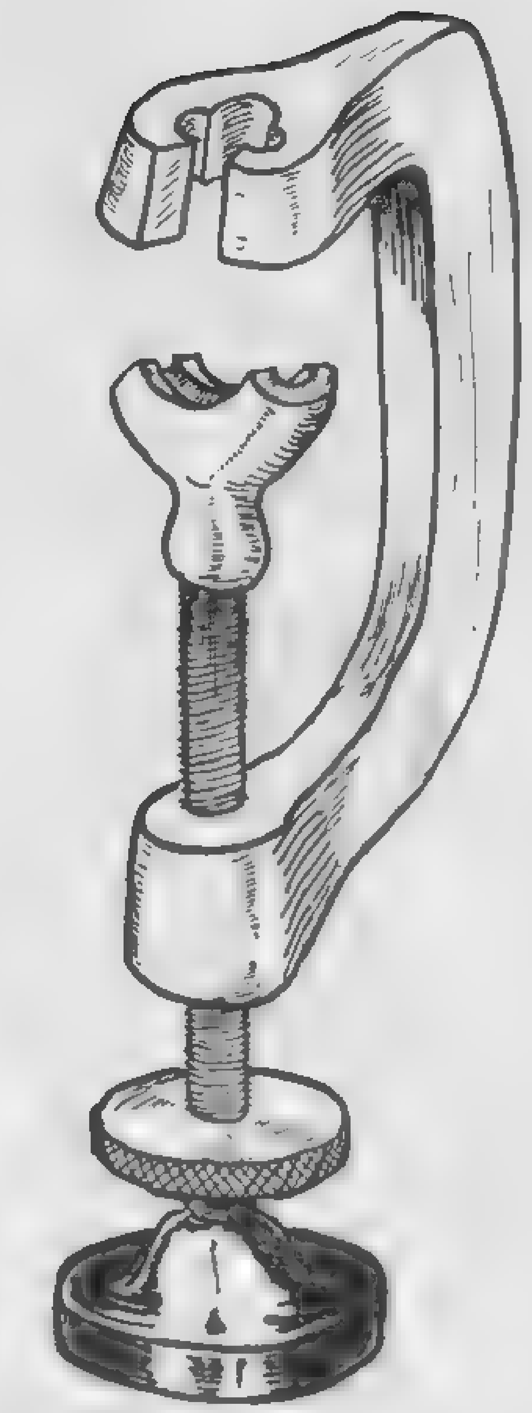


Fig. 2. Clamp for Cable Splicing

Fig. 3. Wire Cutters

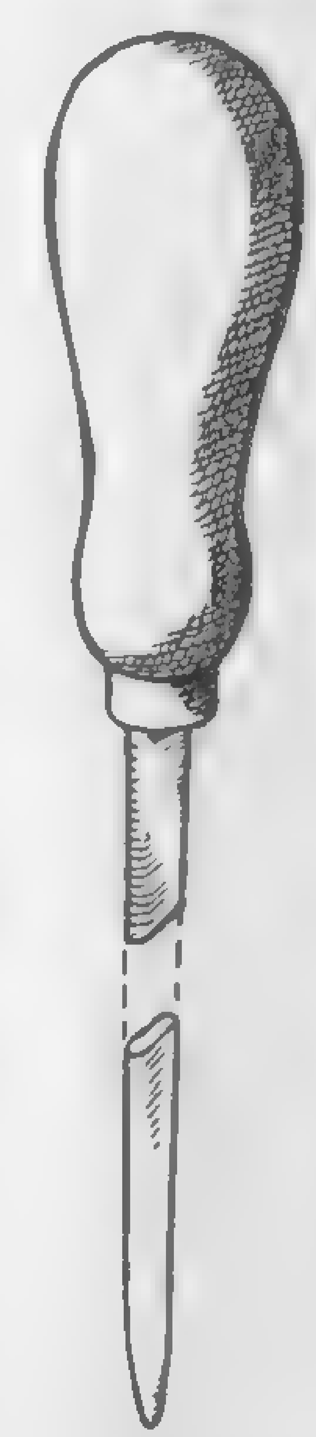


Fig. 4. Marline Spike

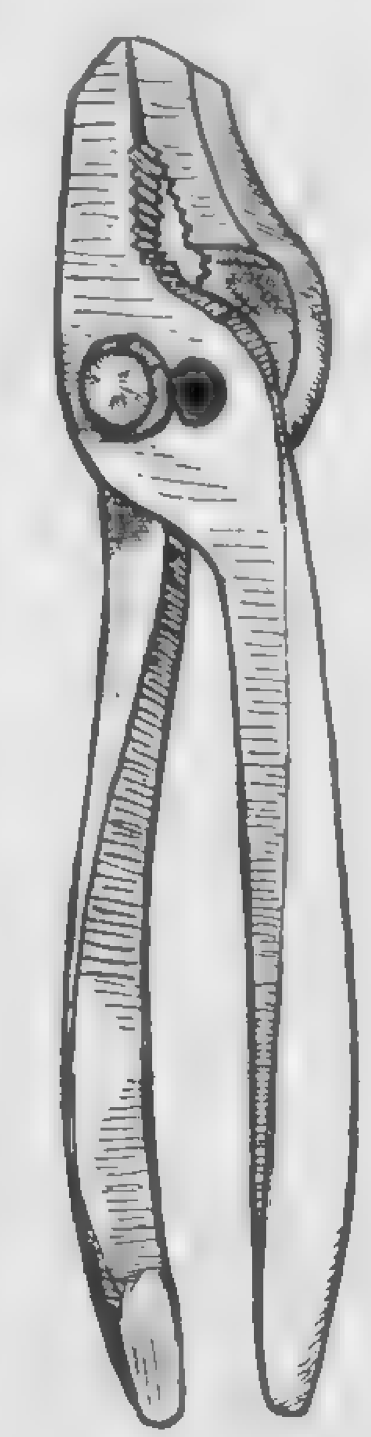


Fig. 5. Pliers

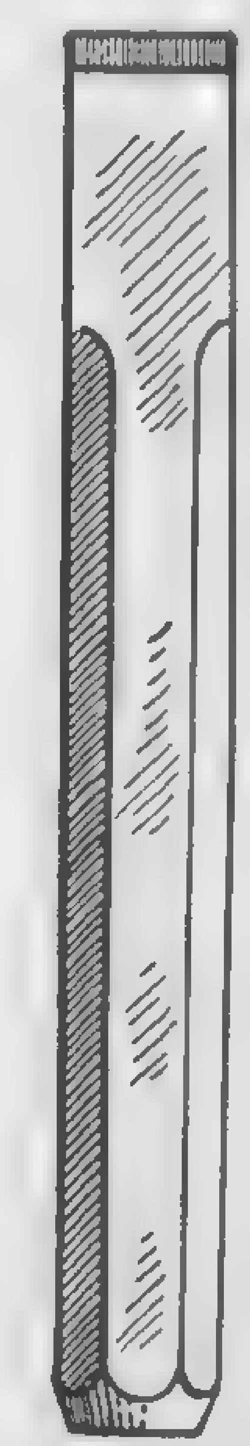


Fig. 6. Cold Chisel

Fig. 7. Hammer

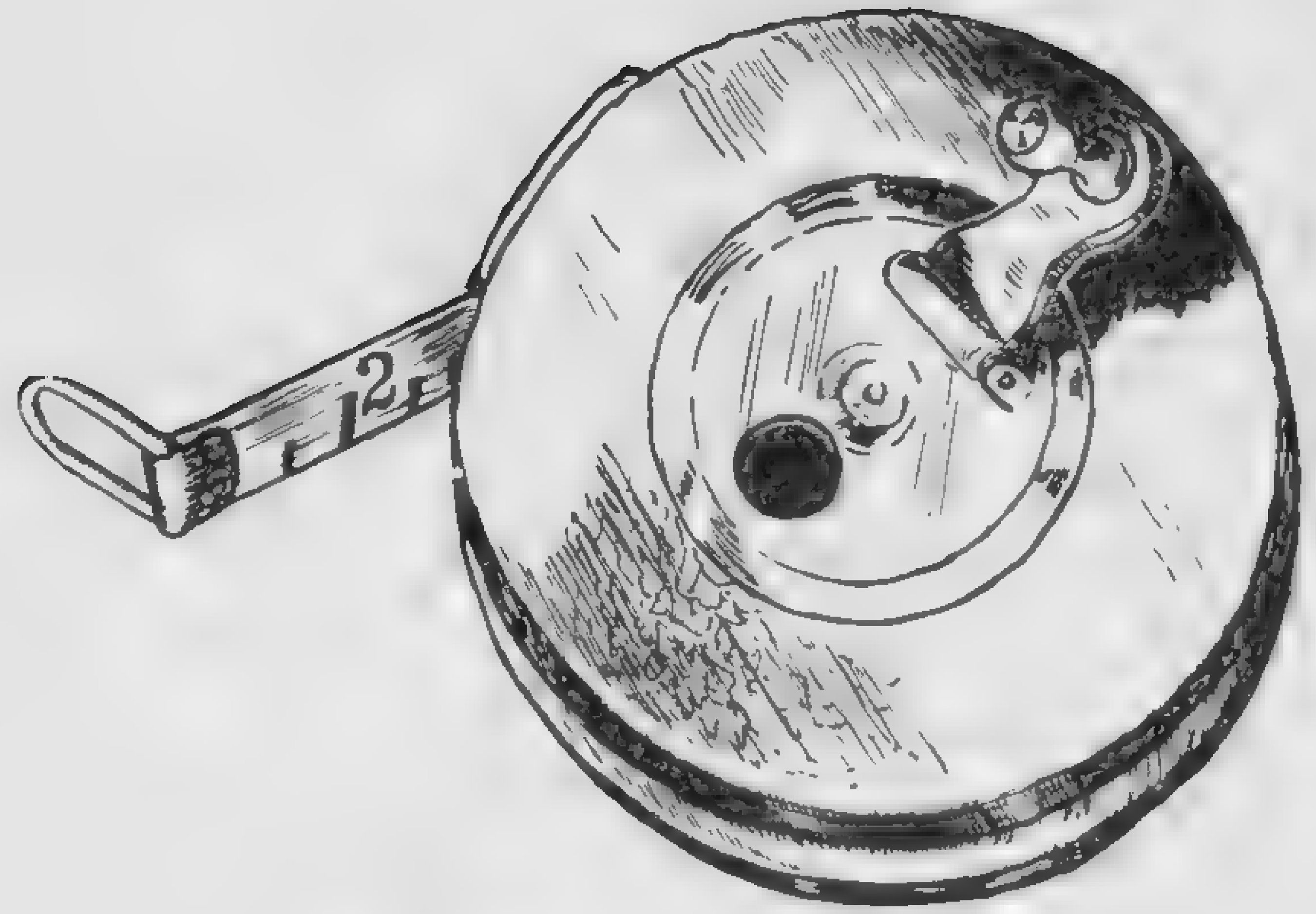


Fig. 8. 50-Foot Steel Tape Measure

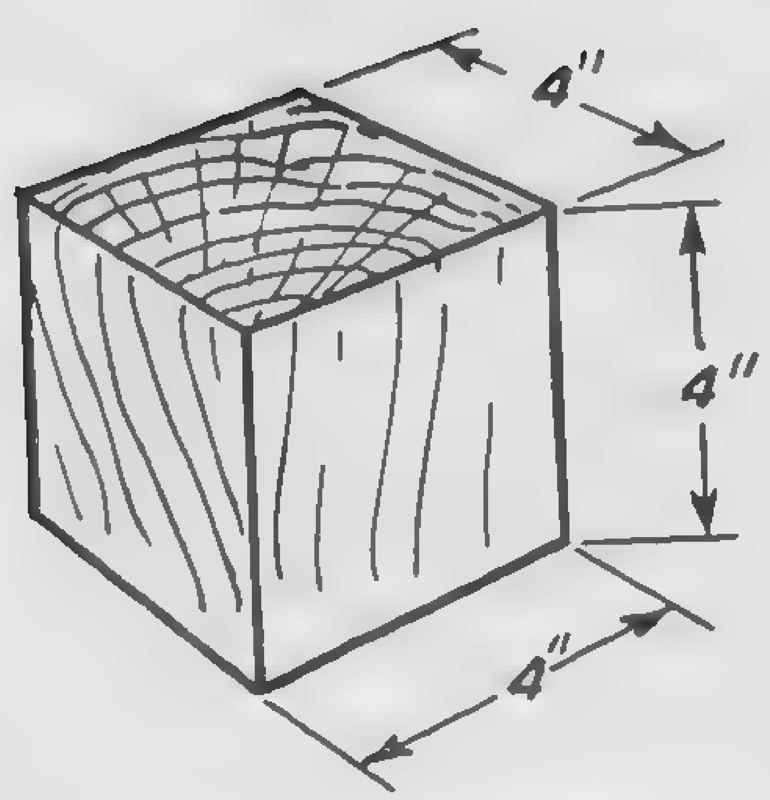



Fig. 9. Hardwood Block


Fig. 10. Thimble

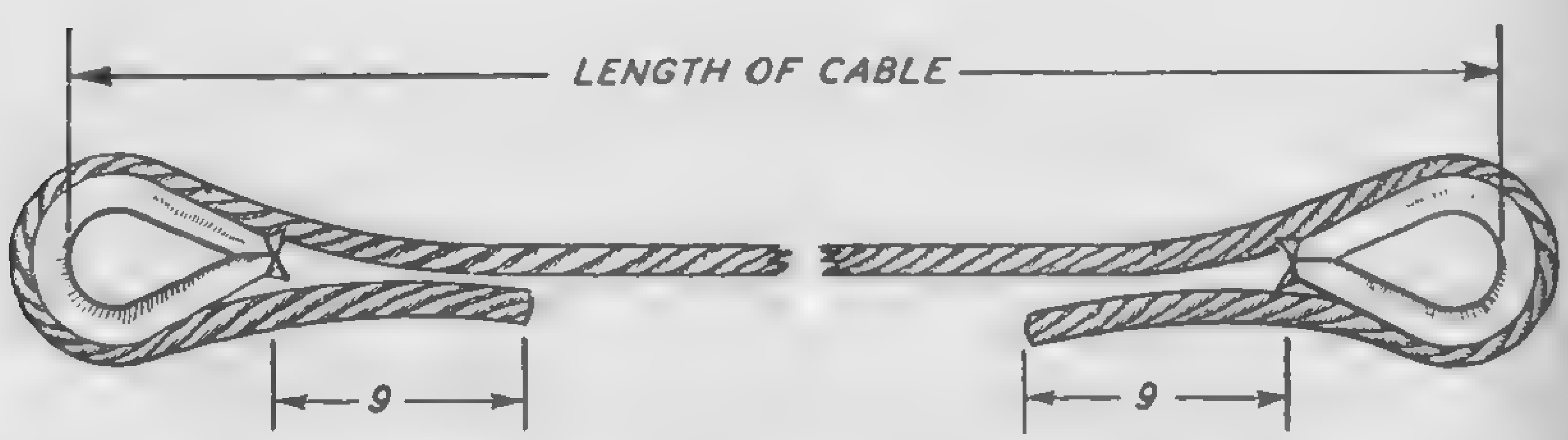



Fig. 11. Measuring the Cable. An Allowance of 18 Inches Is Made for Splicing





## THE FIVE-TUCK SPLICE

### PREPARATIONS FOR SPLICING

While splicing cable the student should wear close fitting leather gloves in order to prevent the wires from pricking the hands. If the hands should be pricked by the wires or spike, apply iodine immediately to prevent infection.

Measure the old cable exactly, from the inside of one thimble to the inside of the other thimble for correct measurements. Add eighteen inches to the new cable so there will be about nine inches extra at each end to make the splice. See Fig. 11. Put the cable in a vise with the measured piece hanging free. Beginning two inches from the vise, wrap the cable, for two inches, with copper wire or copper safety wire as shown in Fig. 12. This helps to keep the heat,

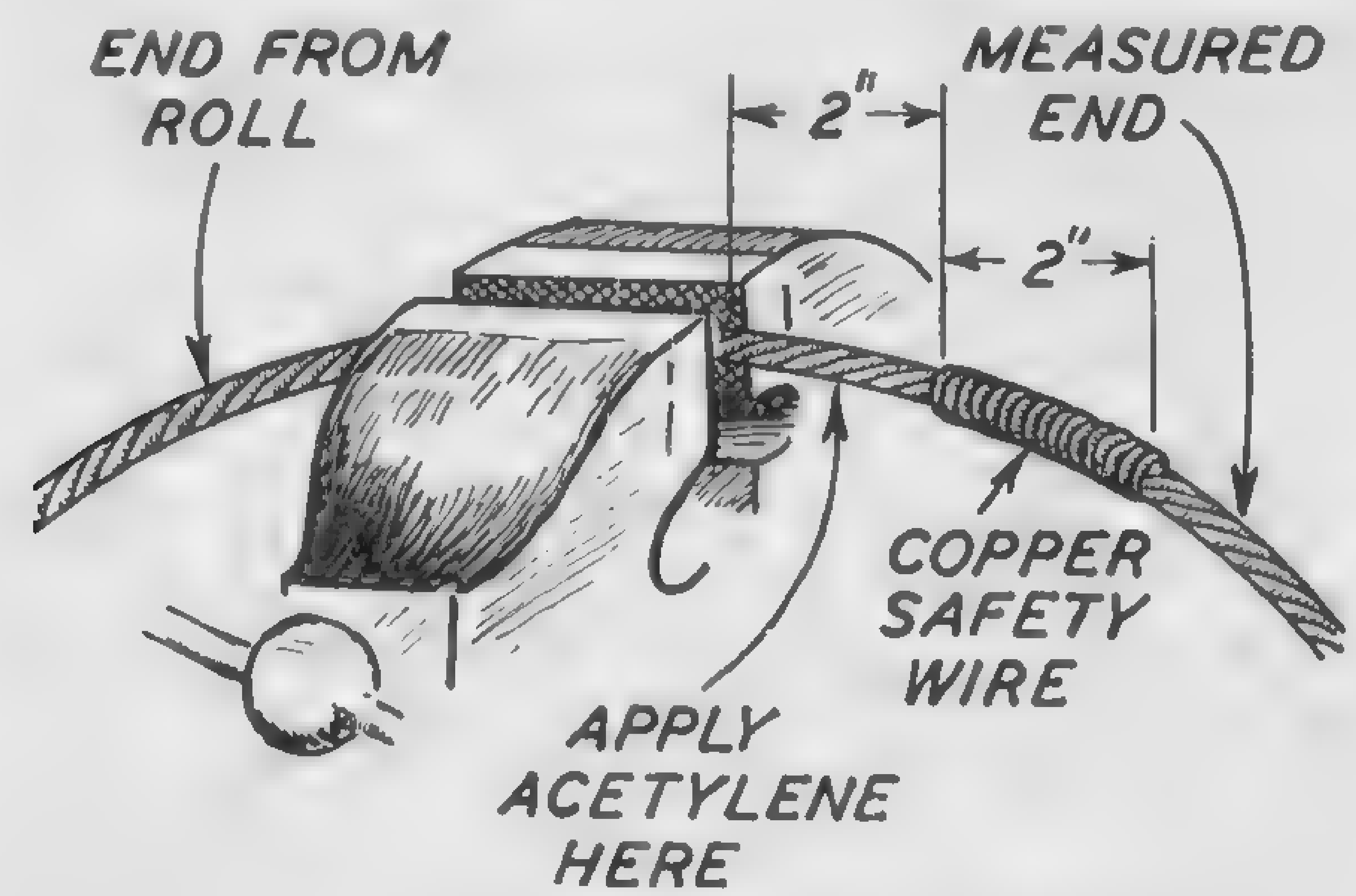



Fig. 12. Cable in the Vise, Ready for the Blowtorch

applied in cutting, from traveling down the cable. Using a blowtorch or acetylene torch, hold the flame far enough away so as not to burn the cable but close enough so it will heat quickly to a cherry red. Let it cool as this will anneal the spot to be cut. Take the cable out of the clamp and put in cold water so that it can be handled.

With the chisel and hammer, cut the cable where it was heated to a cherry red. If not properly annealed, the cable will fray and unravel.

Place thimble and cable in splicing clamp so there is one free end of eight or nine inches. Bend the thimble points back out of the way at a 45-degree angle. See Fig. 10.

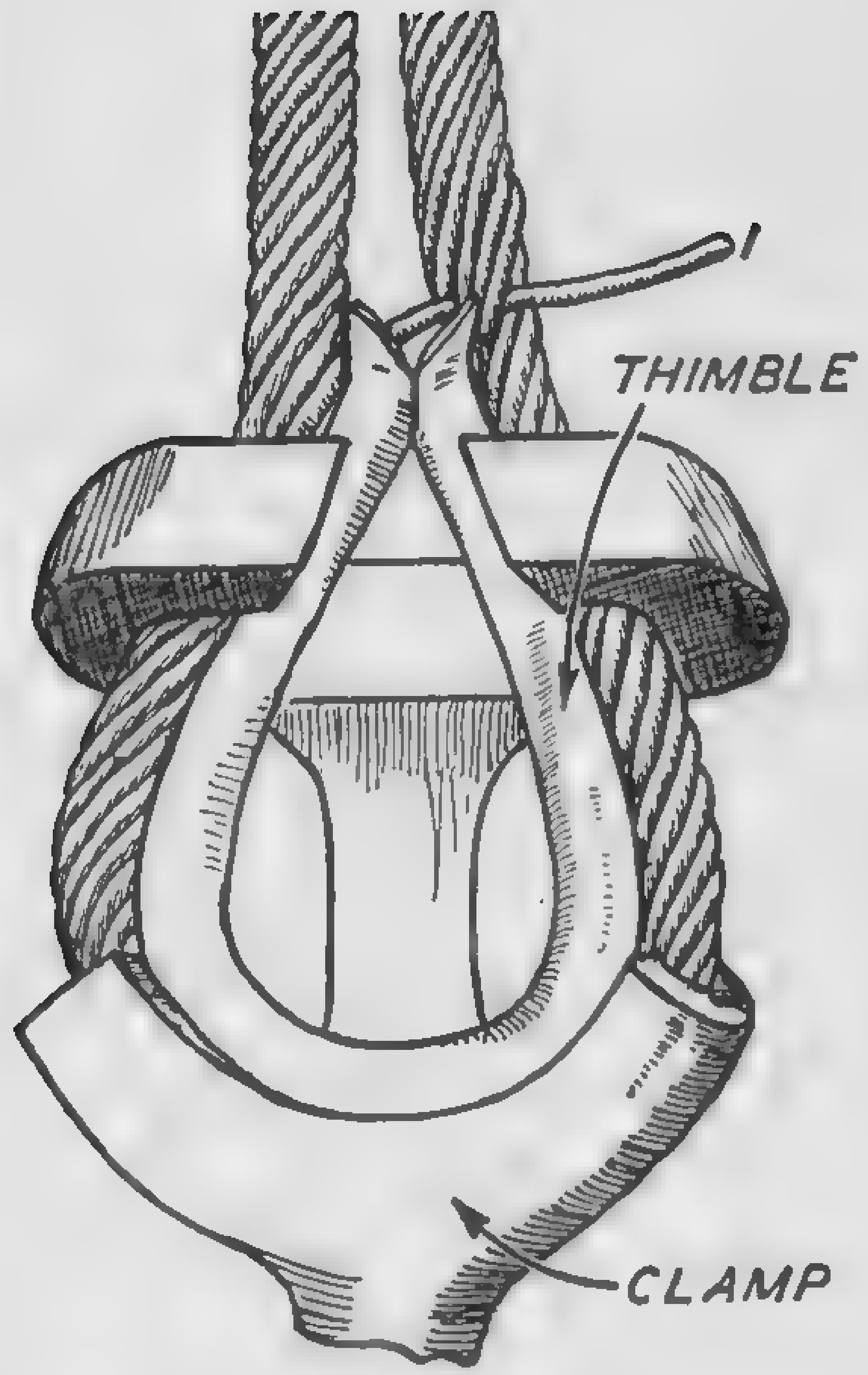



Fig. 13. Cable and Thimble in Clamp, Showing Step 1 of First Tuck

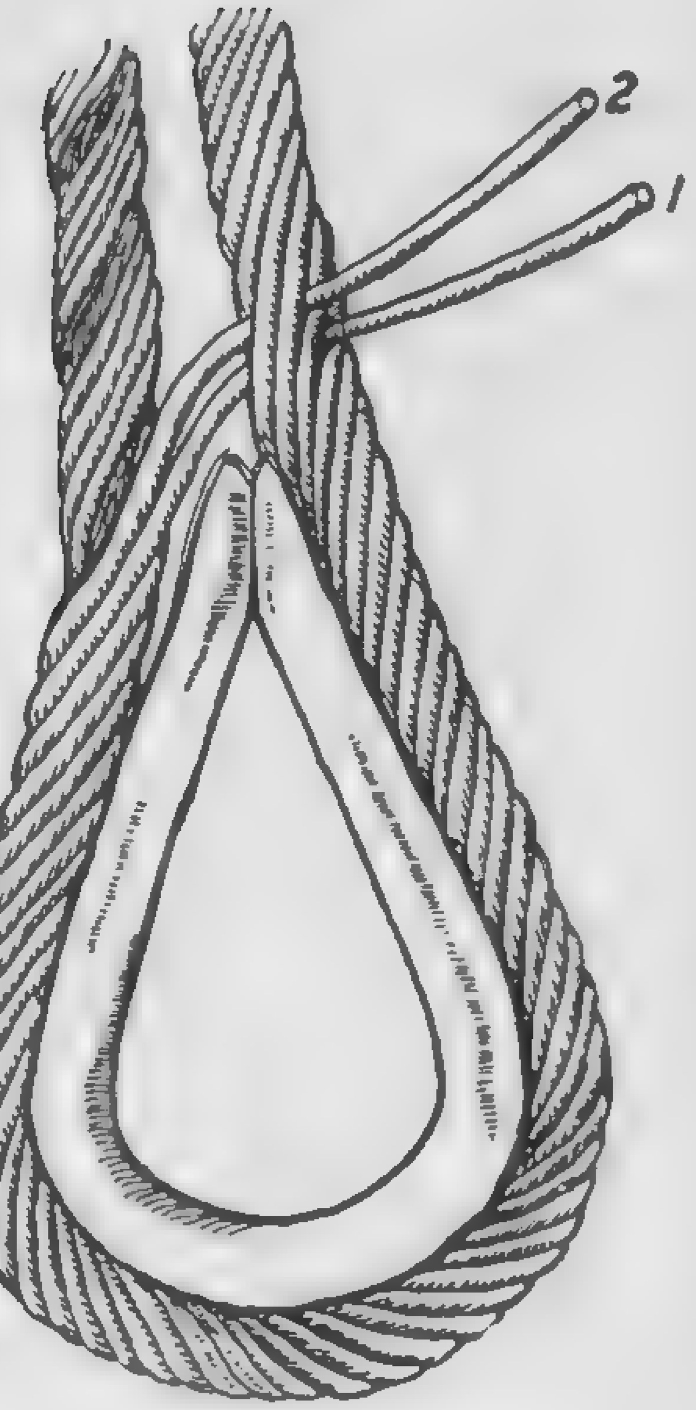



Fig. 14. Step 2 of the First Tuck

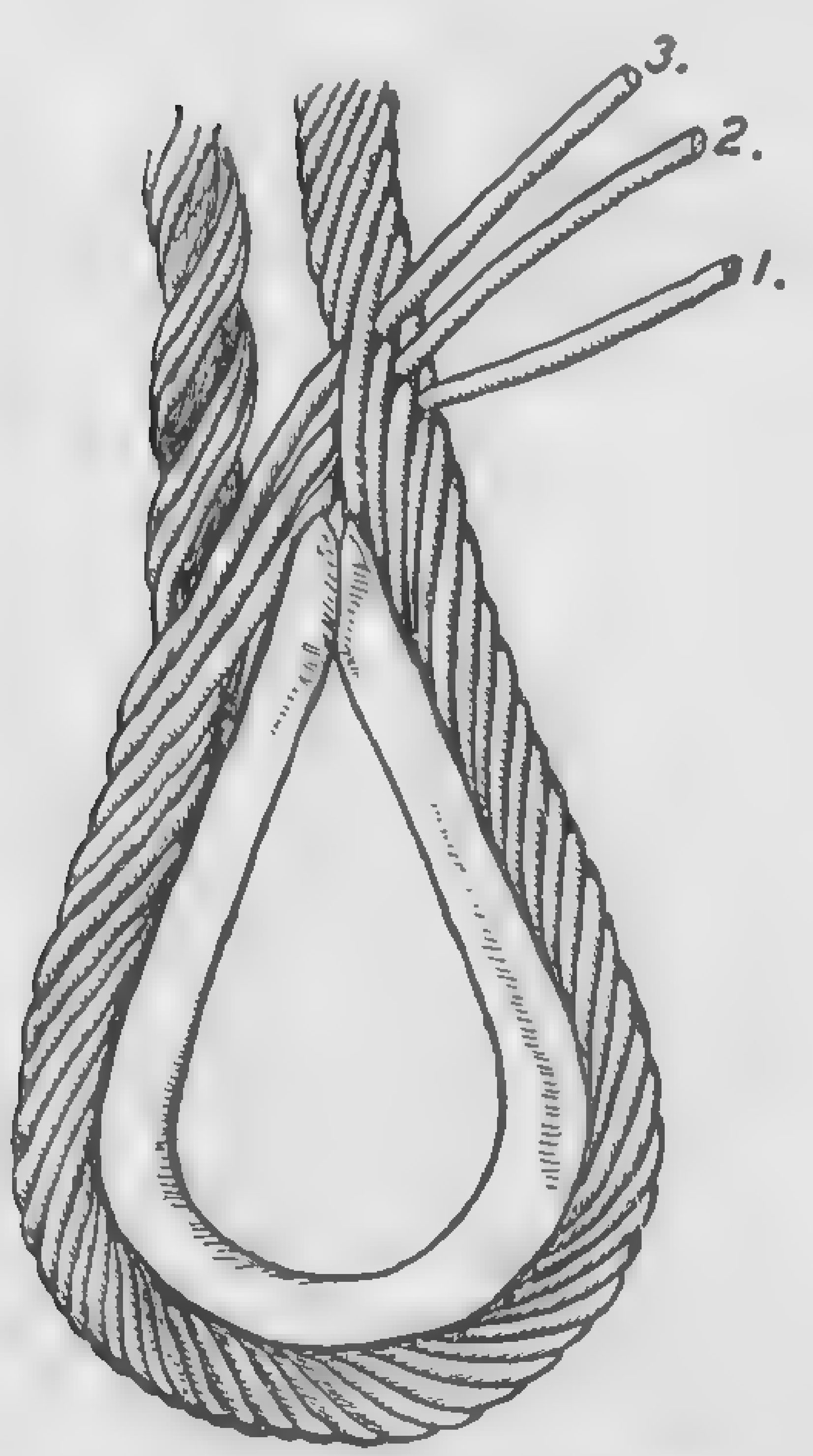



Fig. 15. Step 3 of the First Tuck

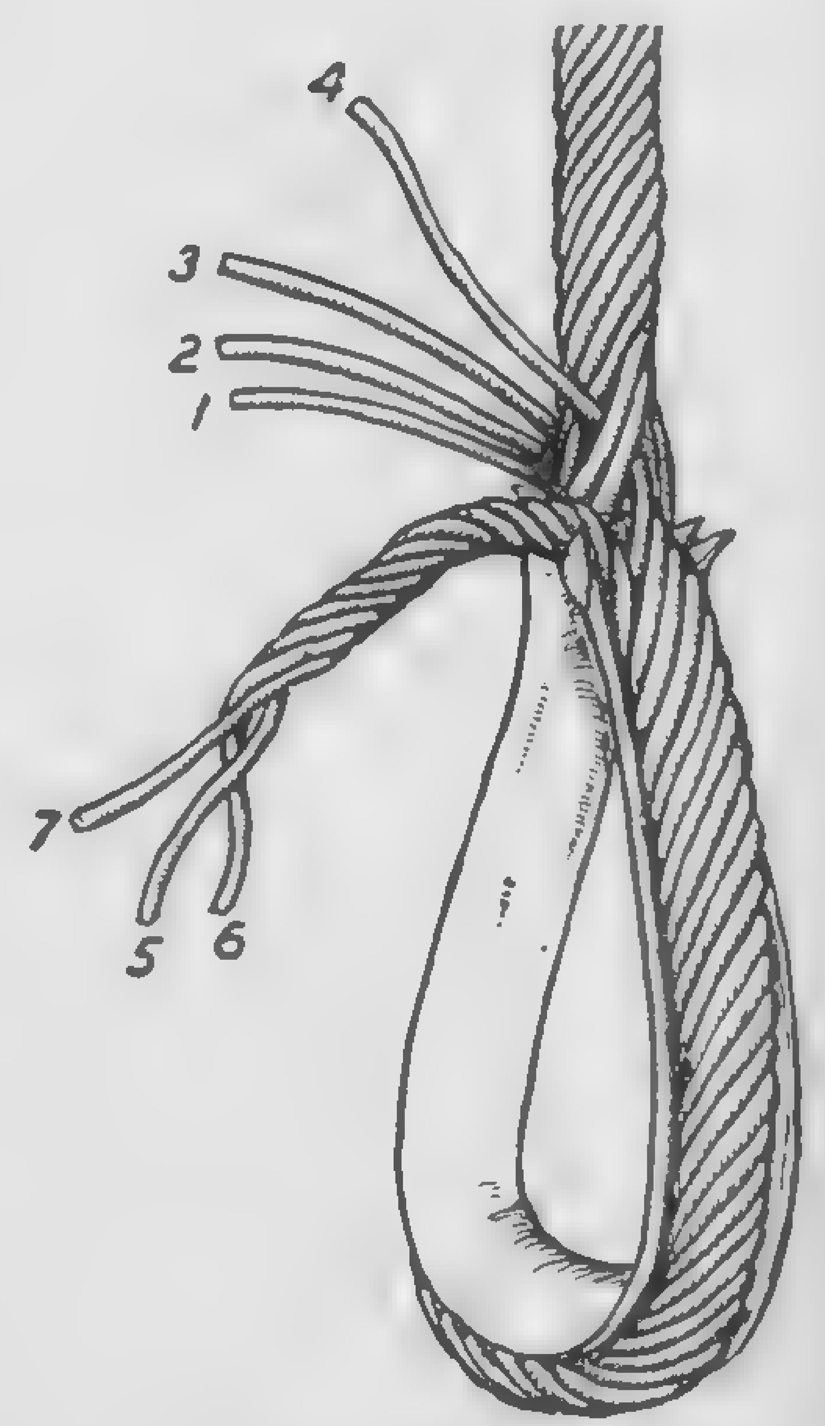



Fig. 16. Step 4 of the First Tuck





## FIRST TUCK

**Step 1.** Hold the cable as shown in Fig. 13. Take the strand nearest the thimble point on the left. This strand is called No. 1. Separate No. 1 strand from the others. With the marline spike lift the three strands nearest the right thimble point of the long cable. Place No. 1 strand under the three strands going left to right, as in Fig. 13.

**Step 2.** Hold the cable in the same position. Loosen the strand to the left of No. 1. This strand is No. 2. It goes in the same place as No. 1 only it goes under two instead of three strands. See Fig. 14.

**Step 3.** Loosen the next strand to the left. This is strand No. 3. Strand No. 3 goes in the same place as strands No. 1 and No. 2, except under one strand, as in Fig. 15.

**Step 4.** Turn the cable over to the opposite side of the thimble. Loosen the strand nearest the right thimble point and separate. This is No. 4. Place the marline spike under the remaining two strands where there are no free strands coming out—this is to the right of No. 1 strand. Run No. 4 under the two strands from right to left as in Fig. 16.

**Step 5.** There are three strands left. One, which is the core strand or No. 5, is perfectly straight. Separate the core strand from the other two. Turn thimble over to the first position. Run the core strand through the same place as No. 2 strand, under two strands. This is the only time the core strand is tucked through. Tie a knot in the core strand so it will not be tucked again. See Fig. 17.

**Step 6.** There are two loose strands left, and one strand in the main cable. Take the next strand, which will be No. 6. Put the marline spike under the strand of the main cable, entering left to right, as in Fig. 18.

**Step 7.** The last strand is No. 7. Run No. 7 in the same direction as No. 6. It enters where No. 4 comes out, going left to right, as in Fig. 19. This completes the first tuck.

The student should notice that a free strand comes out between each strand in the main cable, except where No. 2 free strand and the core strand come out at the same place. Other than this, there should *never* be two strands coming out between the same strands in the main cable.

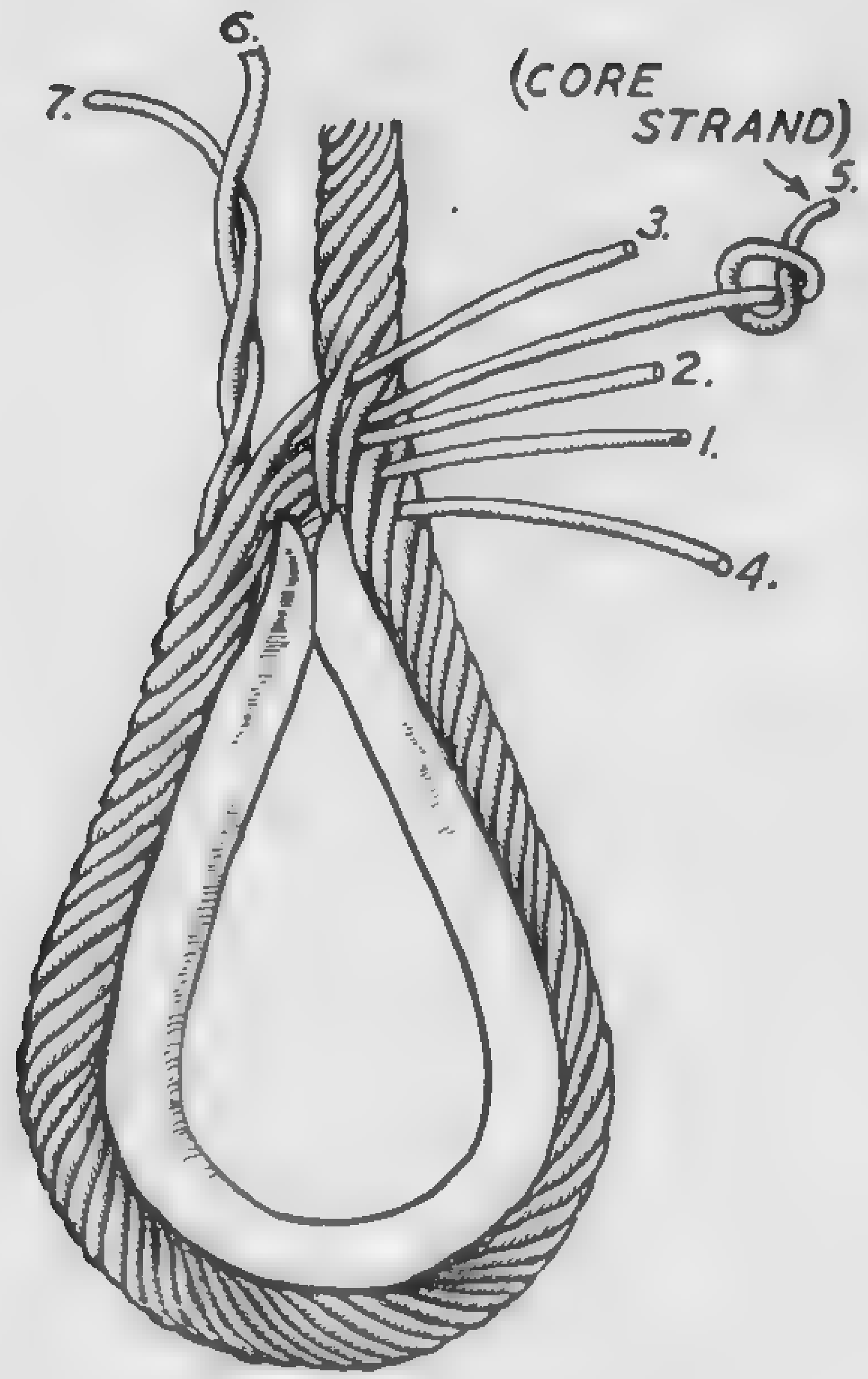



Fig. 17. Step 5 of the First Tuck

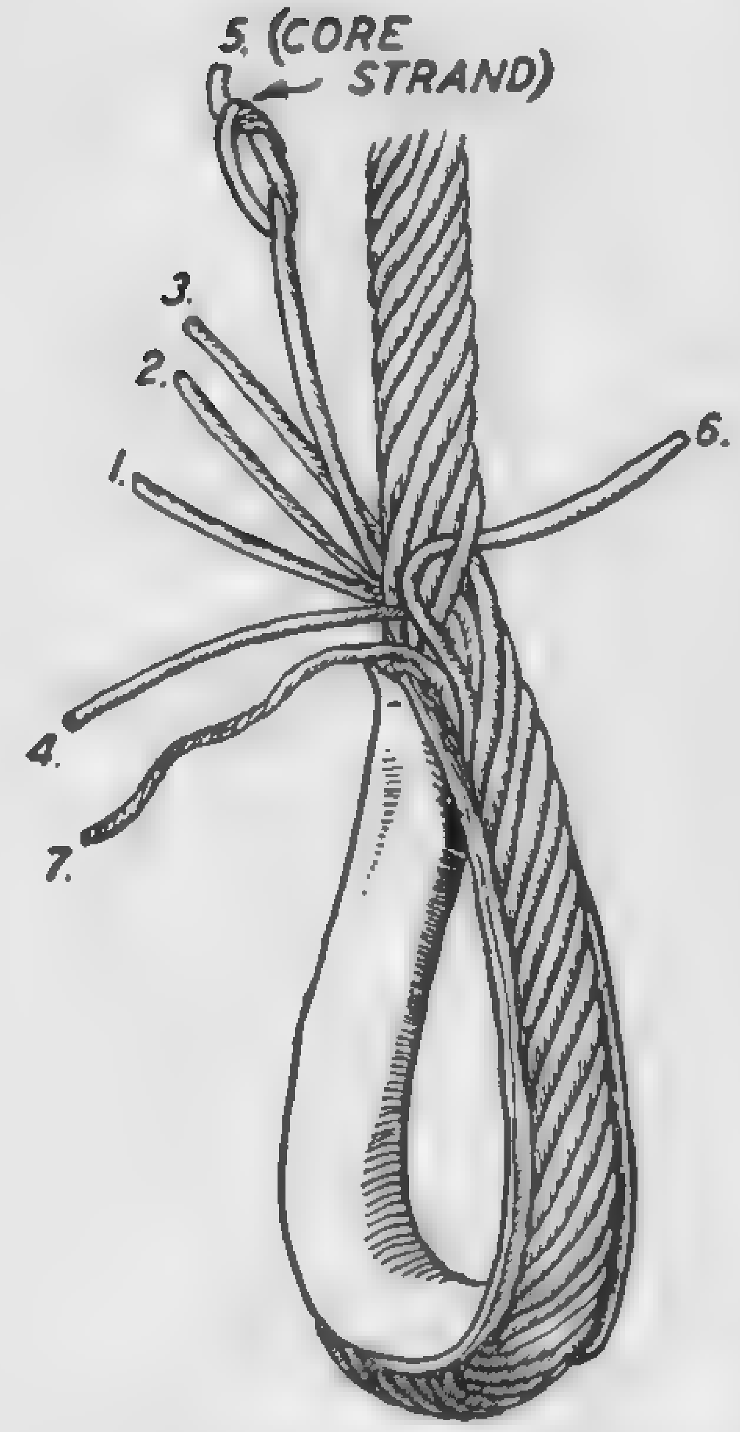



Fig. 18. Step 6 of the First Tuck

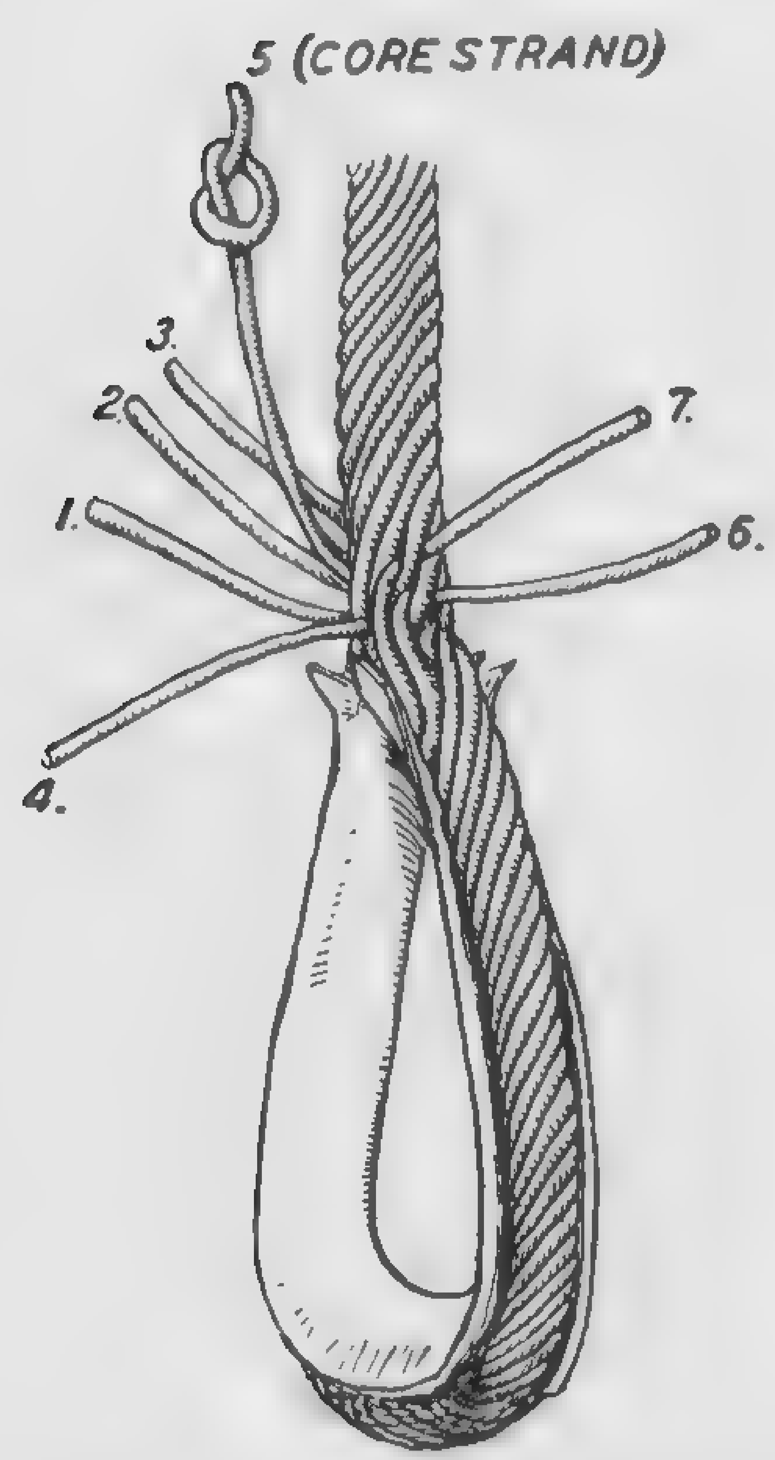



Fig. 19. Step 7 of the First Tuck

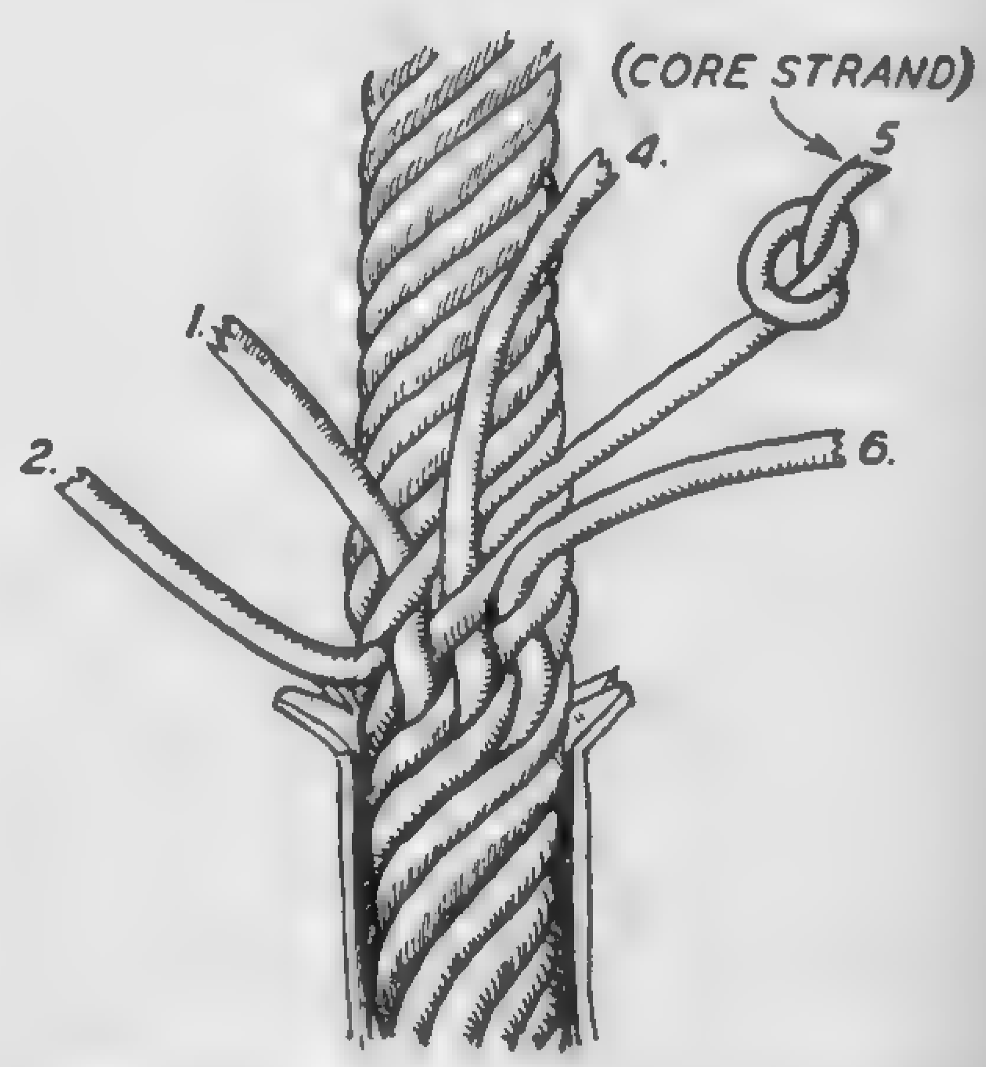



Fig. 20. Steps 1, 2, and 3 of the Second Tuck





To make a good tight splice, each free strand should be pulled down toward the splice clamp with a pair of pliers.

### SECOND TUCK

**Step 1.** Start with No. 1 strand; go over one and under one, going right to left. Bury the core strand underneath. See Fig. 20.

**Step 2.** Take the next free strand to the right, No. 4, go over one and under one from right to left, as in Fig. 20.

**Step 3.** Take next strand to the right, which is No. 6 and go over one and under one from right to left, as in Fig. 20.

**Step 4.** Take No. 7 strand, the next strand, over one and under one, right to left.

**Step 5.** No. 3 strand over one and under one, right to left.

**Step 6.** No. 2 strand over one and under one, right to left.

This completes the second tuck. Again notice that only one strand comes out between each strand except where the core strand comes out with one other strand.

Again pull strands down tight with pliers. *Do not pull core strand.*

Take the cable out of the splicing clamp. Place the two tucks over a hardwood block and beat the cable with a rawhide mallet, turning cable counterclockwise at the same time. The splice is now beginning to take form.

### THIRD TUCK

The third tuck is the same as the second tuck. Cut off the core strand after the tuck is finished.

### FOURTH TUCK

The fourth tuck is the same as the third, except that each strand is divided in half and the half strands are tucked. See Fig. 21. Cut off the unused half strands after the other six half strands have been tucked. Beat splice as before.

### FIFTH TUCK

Divide each half strand and tuck the same as No. 4 tuck. Cut off remaining quarter strands, as in Fig. 22.

The splitting of strands gives the splice a taper. Take out of holder again and beat as after the second tuck, turning counter-

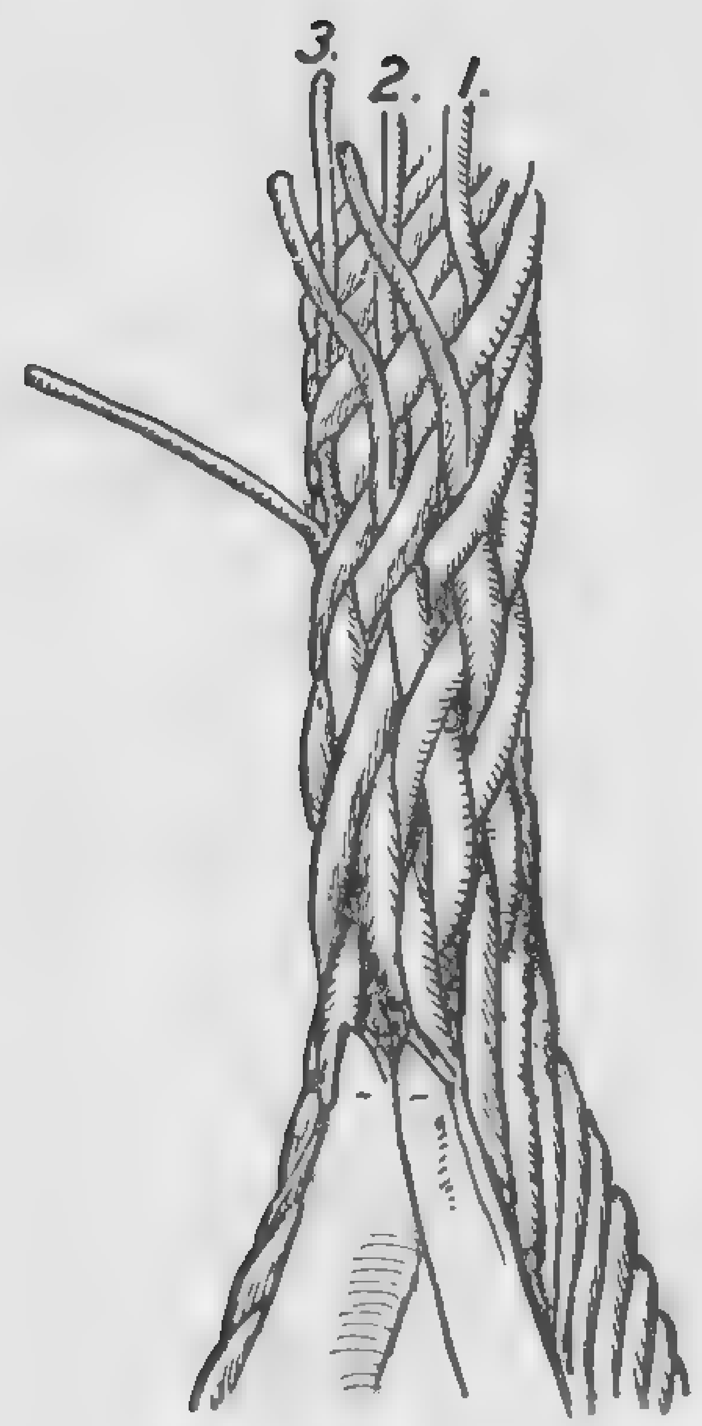



Fig. 21. The Fourth Tuck, Showing Split Strands

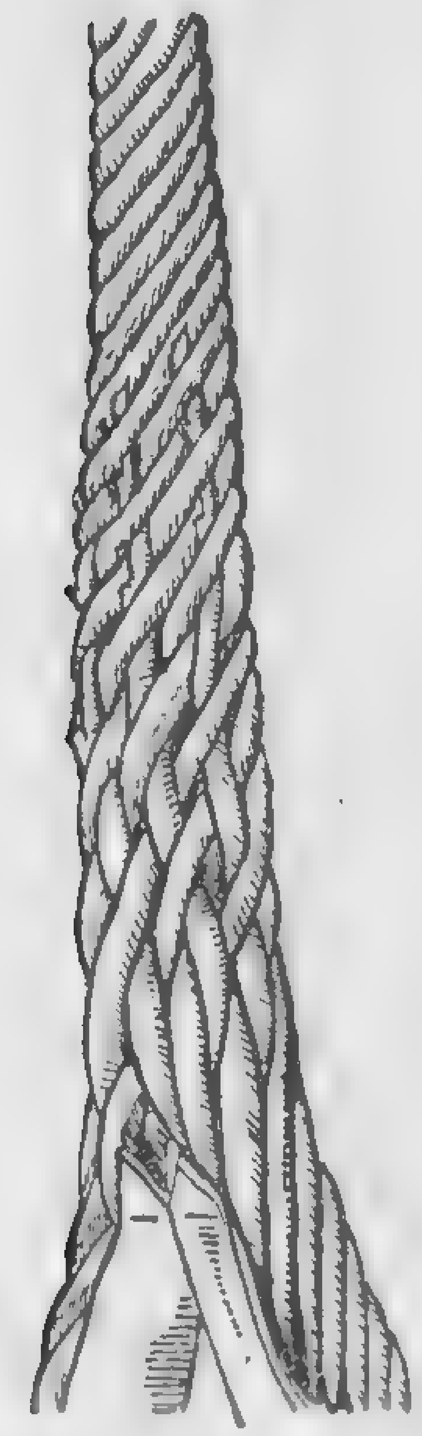


Fig. 22. The Fifth Tuck Completed, Ready for Serving

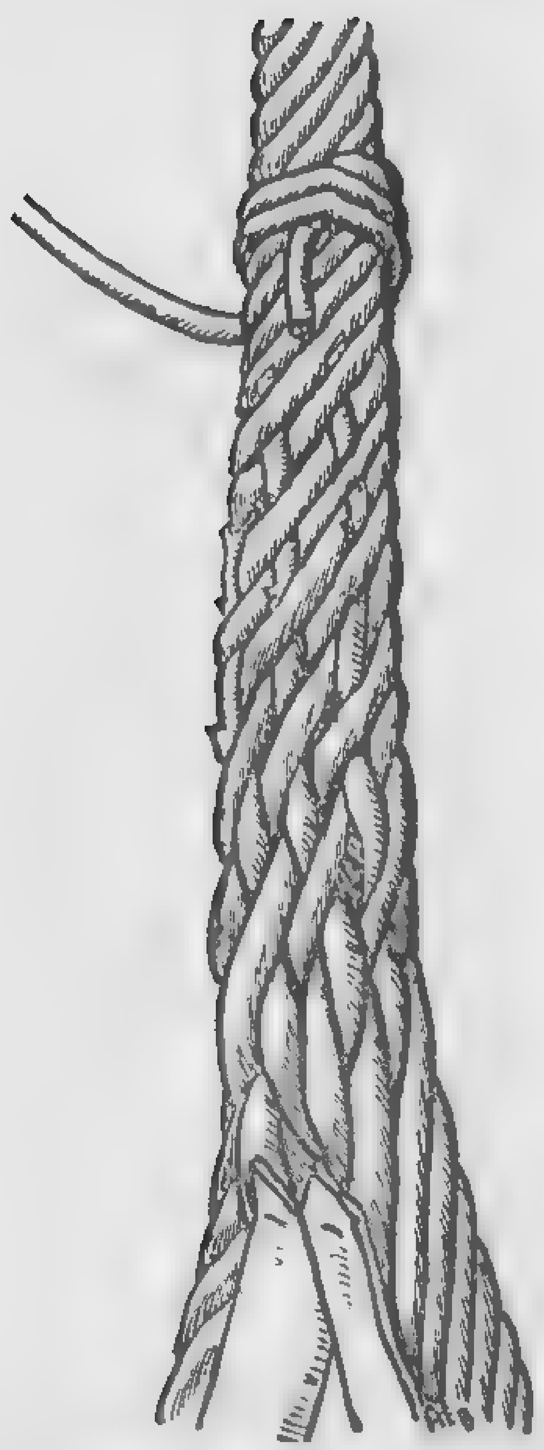


Fig. 23. Disposal of the First End of Serving Cord

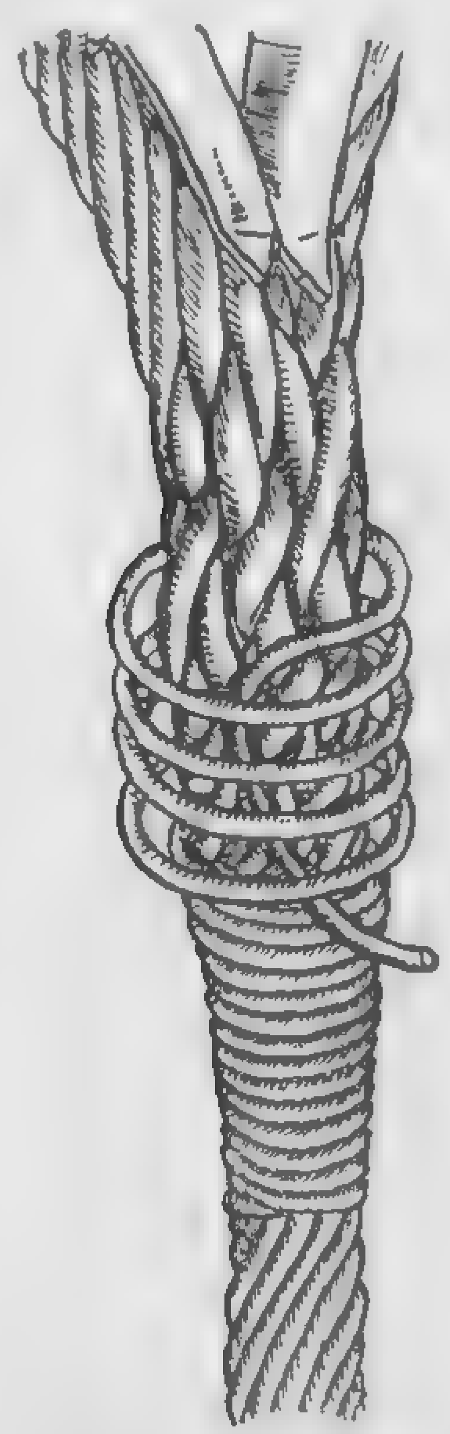


Fig. 24. Disposal of Second End of Serving Cord

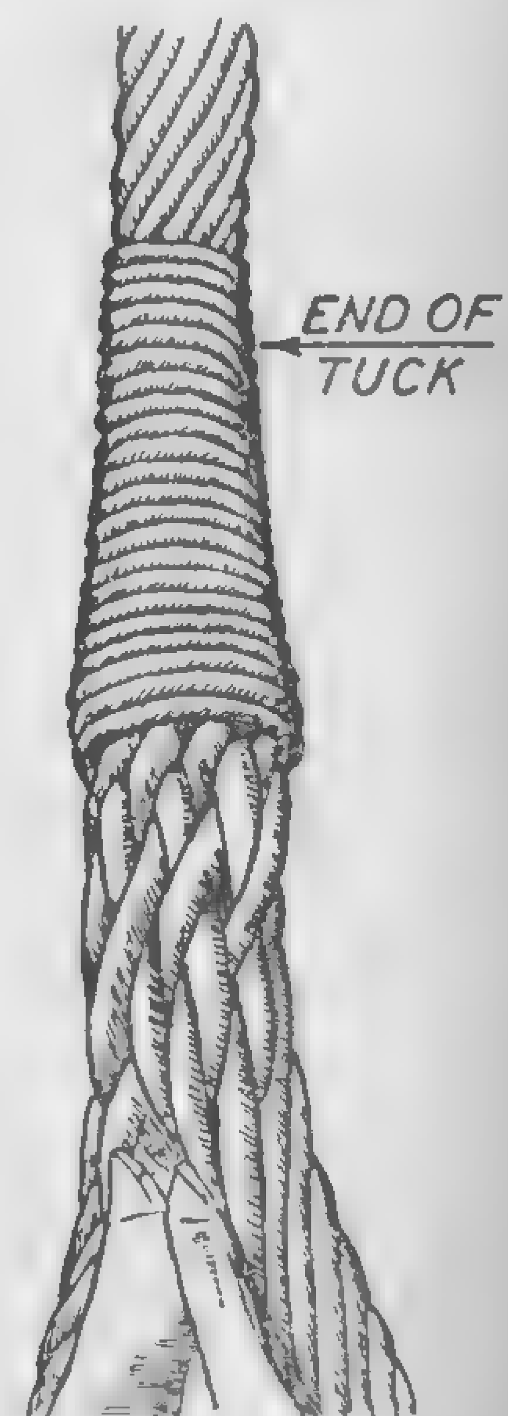



Fig. 25. The Finished Five-Tuck Splice





clockwise. Also beat thimble points down into shape. This will tighten the splice and shape it. Cut off all free loose strands. At this point the splice should always be inspected by a government-licensed man before it is wrapped. Wrap the splice with No. 6 waxed linen cord. This operation is called "serving."

Start serving about ¼ of an inch beyond the end of the taper. Fig. 23 shows the disposal of first end of the cord. Wrap until all is covered smoothly. Be sure all of the sheared ends of the strands are covered but do not wrap below the third tuck. Take five or six loose coils over thumb or finger and insert the end of the serving cord through the loose coils from the thimble and toward the taper. Now slip from the finger and tighten the loose coils firmly over the inserted end. Pull up any slack by drawing the inserted end down toward the taper. Fig. 24 illustrates disposal of the second end of the cord. Cut off close to the serving, and beat it lightly with the mallet to smooth it down. Then add two coats of shellac to make the splice as nearly waterproof as possible. This finishes the five-tuck splice. The splice as it should look when finished is shown in Fig. 25.

TABLE OF TEST LOADS

| Cable Diameter Inch | Test Load Pounds | Cable Diameter Inch | Test Load Pounds |
|---|---|---|---|
| 1/16 | 250 | 3/16 | 2500 |
| 3/32 | 550 | ¼ | 4200 |
| 1/8 | 1200 | 9/32 | 4800 |
| 5/32 | 1700 | 5/16 | 6000 |

Cables and splices failing to withstand the test loads specified shall be rejected.

LINE CHIEF AT RANDOLPH FIELD, TEXAS, WITH STUDENT PILOTS
*Official Photograph, U. S. Army Air Forces*



PART 3

# Electrical Wiring and Splicing

## FIELD WIRE LINE CONSTRUCTION

Field wire lines are constructed of insulated field wire or commercial substitutes. They are used within the zone subject to hostile shell fire and in rear areas when time does not permit of other types of construction. The wire systems of the infantry and its units normally consist of field wire lines.

## TYPES OF FIELD WIRE

Two types of field wire are issued. Both conductors of both types are insulated with rubber compound and weatherproof braid. Their characteristics and approximate transmission distances are shown in the following table.

| Characteristics | Wire 110 | Wire 110-B |
|---|---|---|
| Number of conductors.... | 2 twisted ............. | 2 twisted |
| Tensile strength .......... | 340 pounds ........... | 246 pounds |
| Satisfactory transmission distance: | | |
| Unloaded ........... | 10–15 wire miles........ | 11–17 wire miles |
| Loaded ............. | 14–22 wire miles........ | 16–24 wire miles |
| Issued: | | |
| On reel DR-4......... | 2,400 feet ............. | 2,400 feet |
| On reel DR-5......... | 1 mile ................. | 1 mile |
| In coils ............. | 1,000 feet ............. | 1,000 feet |
| Weight: | | |
| Wire alone .......... | 132 pounds per mile.... | 132 pounds per mile |
| Reel DR-4 filled...... | 82 pounds ............ | 82 pounds |
| Reel DR-5 filled...... | 166 pounds ........... | 166 pounds |
| Conductor: | | |
| Composition ......... | 5 steel and 2 copper strands | 4 steel and 3 copper strands |
| Tensile strength....... | 200 pounds ........... | 145 pounds |
| Resistance .......... | 130 ohms per mile...... | 95 ohms per mile |

## WIRE SPLICES

The kind of splice depends upon the types of wire to be connected. The installation may require the splicing of field wire to field wire, of field wire to solid conductor wire, either bare or insulated, or of one solid conductor to another. In making splices there are three cardinal principles to be observed. If they are observed, the resulting splice will have all the inherent qualities of the wire itself. These principles are:

Conductivity of the wire must not be impaired;

Insulation resistance must not be decreased; and

Tensile strength of the wire must not be materially decreased.

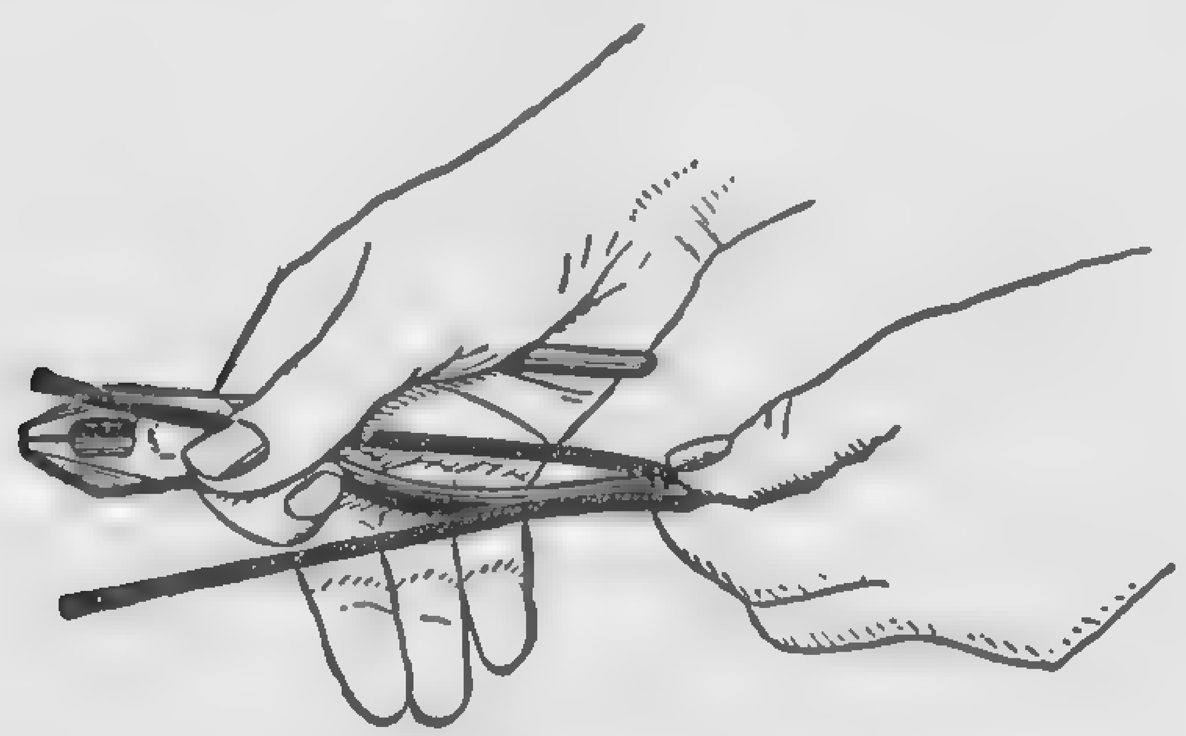


Fig. 1. Staggering Splice

**Field Wire Splice.** The standard field wire splice, utilizing copper seizing wire, is used to splice all types of stranded conductor field wire. Every soldier engaged in communication work should be able to make a proper wire splice. Occasions constantly arise in which such ability is necessary. It is therefore important that the entire unit be trained for this work.

*Teamwork in Splicing.* When making splices it often happens that more than one man is available at the time the splice is being made. In that case, the over-all time for the splice can be greatly reduced if the two men have a standard cooperative method and function as a team. Only the teamwork splice is described, since the same procedure can be followed by one man working alone.

*Staggering Splice.* (Fig. 1.) Each man prepares one of the two wires which are to be spliced together. To obtain a uniform stagger, each man measures back one plier's length (about 6 inches) from





the end of one conductor of the wire he is preparing, and cuts off the conductor thus measured. Each man now has two conductors, with one cut so as to be one plier's length shorter than the other.

*Crushing Insulation.* Each man now begins crushing the insulation on his long conductor at the point where the short one ends, that is, one plier's length from the end of the long conductor. (See Fig. 2.) Using the heel of his pliers, he crushes the insulation toward the end for a distance of about 4 inches, leaving about 2 inches of the insulation uncrushed on the end of the conductor.

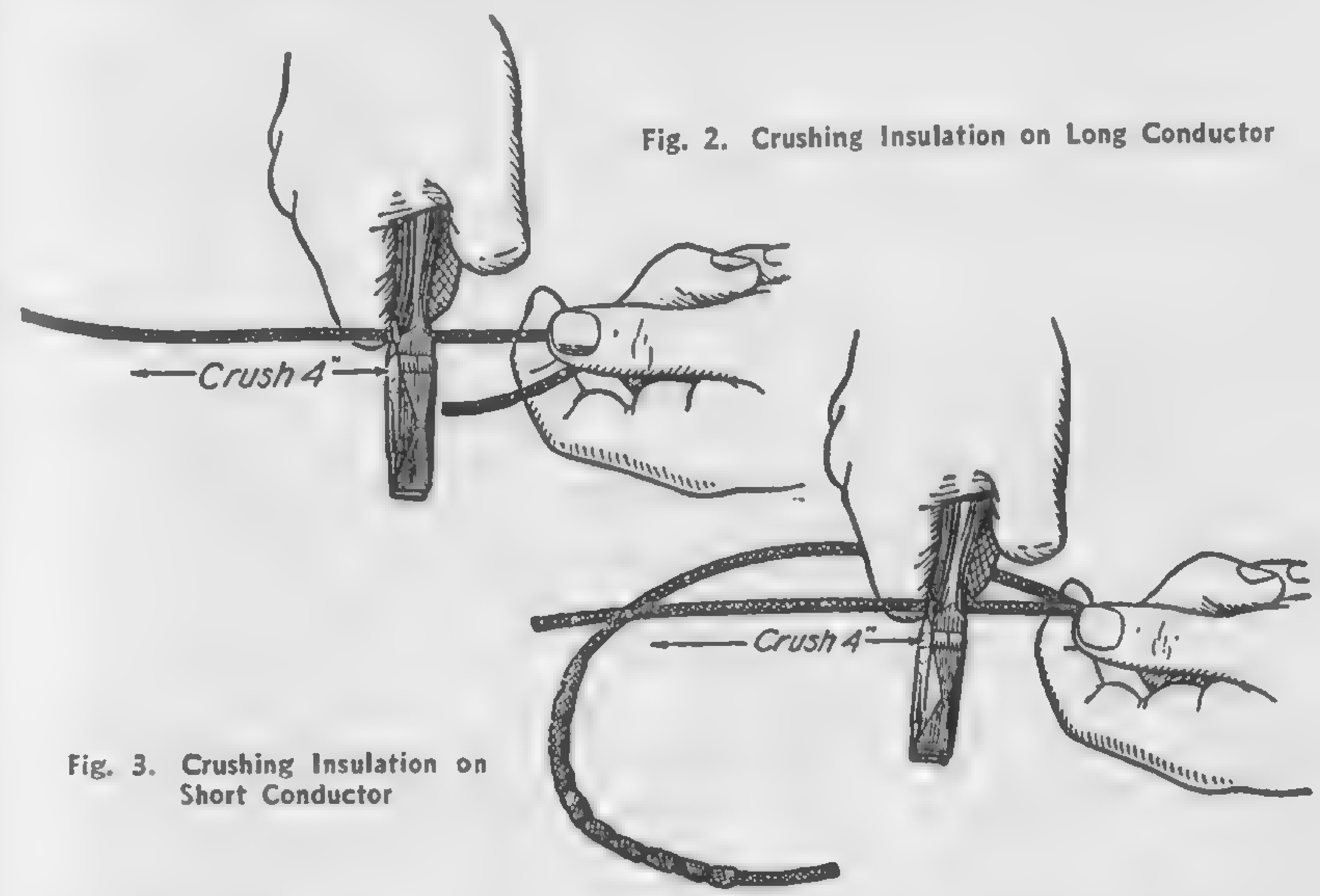



Fig. 2. Crushing Insulation on Long Conductor

Fig. 3. Crushing Insulation on Short Conductor

He next measures back one plier's length along the short conductor, and in a similar manner crushes about 4 inches of its insulation. (See Fig. 3.) The uncrushed insulation remaining on the ends of the conductors holds the strands of the conductor together, prevents possible injury by the steel strands to the splicer, and greatly reduces the over-all splicing time. The two operations described above give a uniform stagger to insure equal tension on both conductors of the wire when the splice is completed.

*Skinning Conductor.* Each man scores or rings the crushed insulation of both conductors with the cutting edges of his pliers at a point about ½ inch from the point at which the crushing began. Then, changing the hand grip on his pliers as shown in Fig. 4, he

draws the cutting edges of his pliers straight along the conductor so as to push the crushed insulation ahead of the pliers. In this operation, care is taken to draw the pliers perpendicularly along the conductor, as drawing the pliers at any appreciably different angle to the conductor will nick or break the strands thereof. He

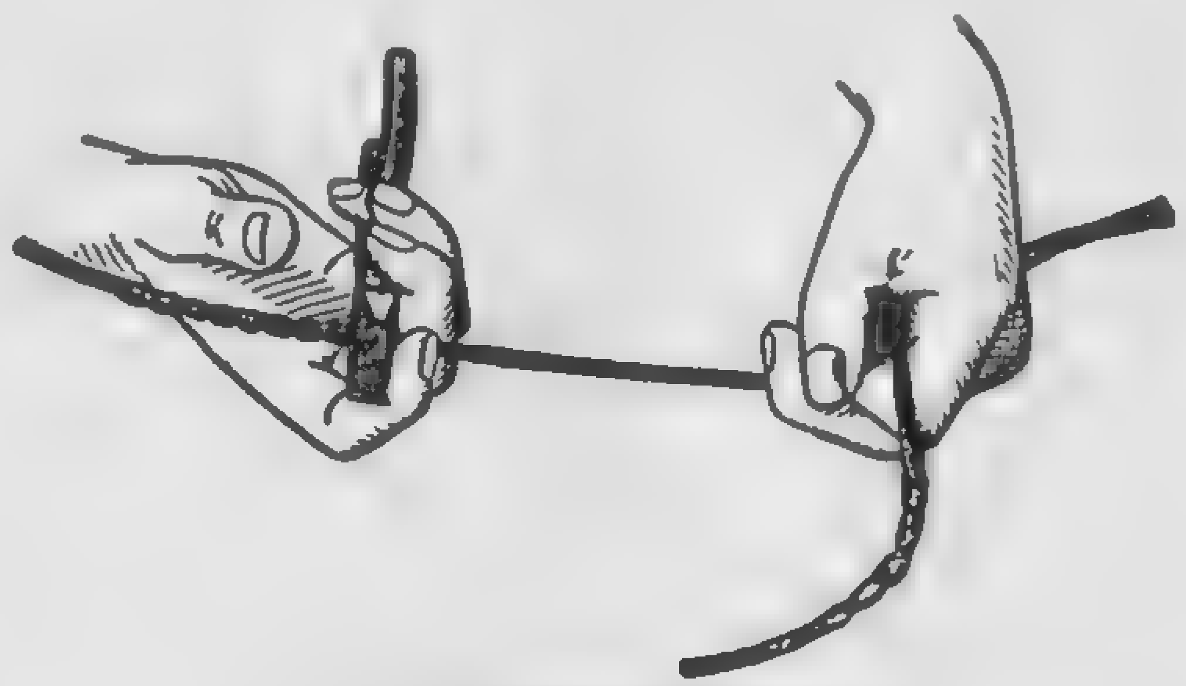


Fig. 4. Skinning Conductor

Fig. 5. Wires Skinned and Ready for Square Knots

then bares about 3½ inches of the strands of the conductor. Although slower, this skinning may be done satisfactorily with less danger to the strands by using the gripping jaws, or the heel of the pliers, instead of the cutting edges. If these strands appear dirty, he carefully scrapes them with the back of the screw driver blade of his electrician's knife. The entire procedure of staggering the splice, crushing the insulation, and skinning the wire should not take over 1 minute.

*Tying Square Knot.* The ends of the two wires are now brought together, and the long conductor of one wire and the short conductor of the other are tied in a square knot by each man, Fig. 5. The square knot is so placed as to leave a distance of about ¼ inch between the knot and the rubber insulation. The weather-





proof braid of the conductor is then peeled back from the ½ inch of wire that was crushed but not skinned. This leaves ½ inch of

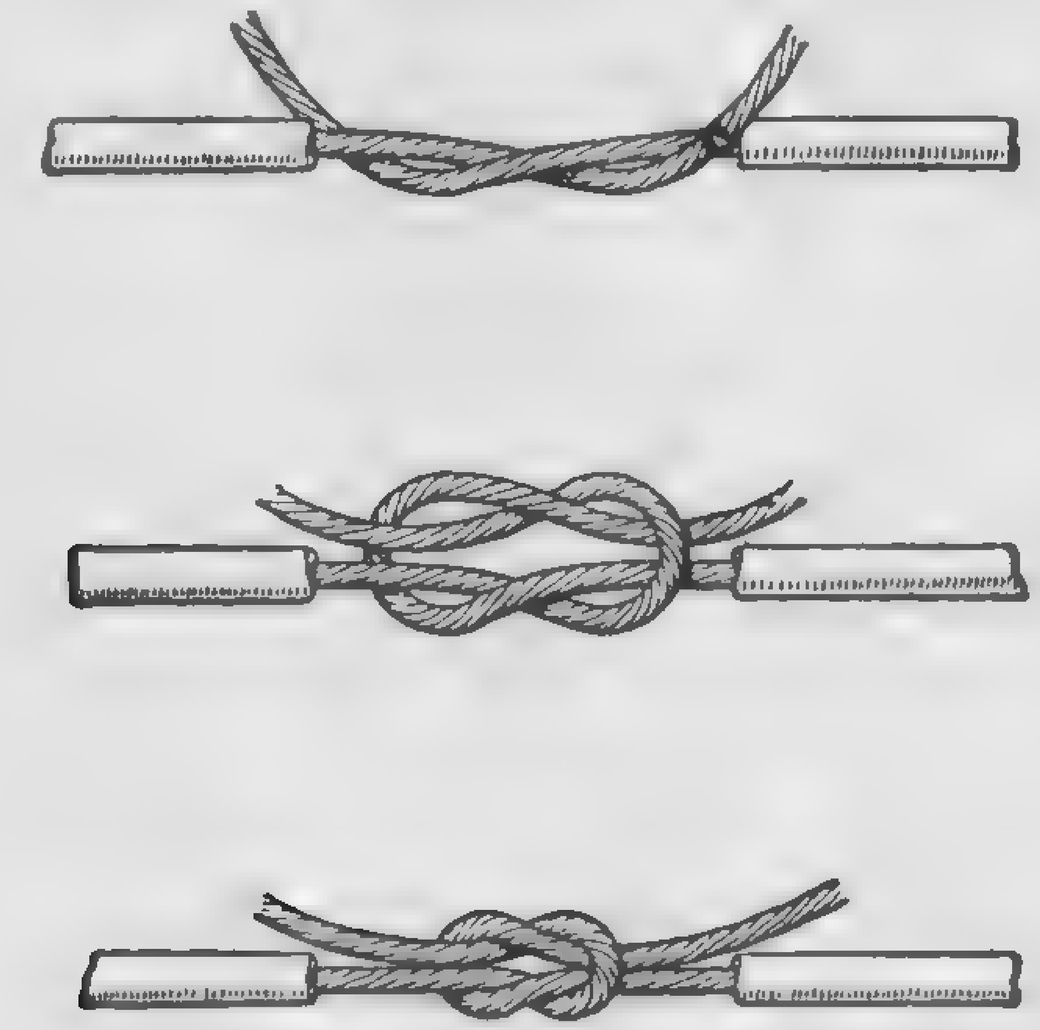


Fig. 6. Tying Square Knot

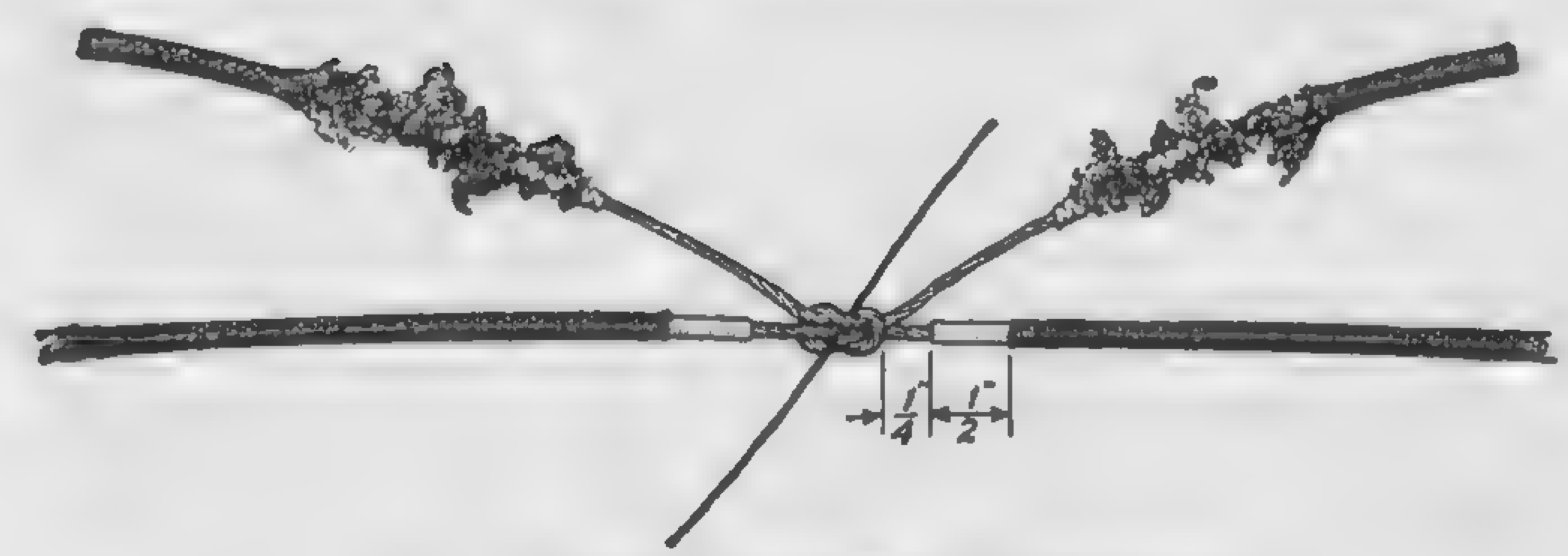


Fig. 7. Seizing Wire Inserted through Knot

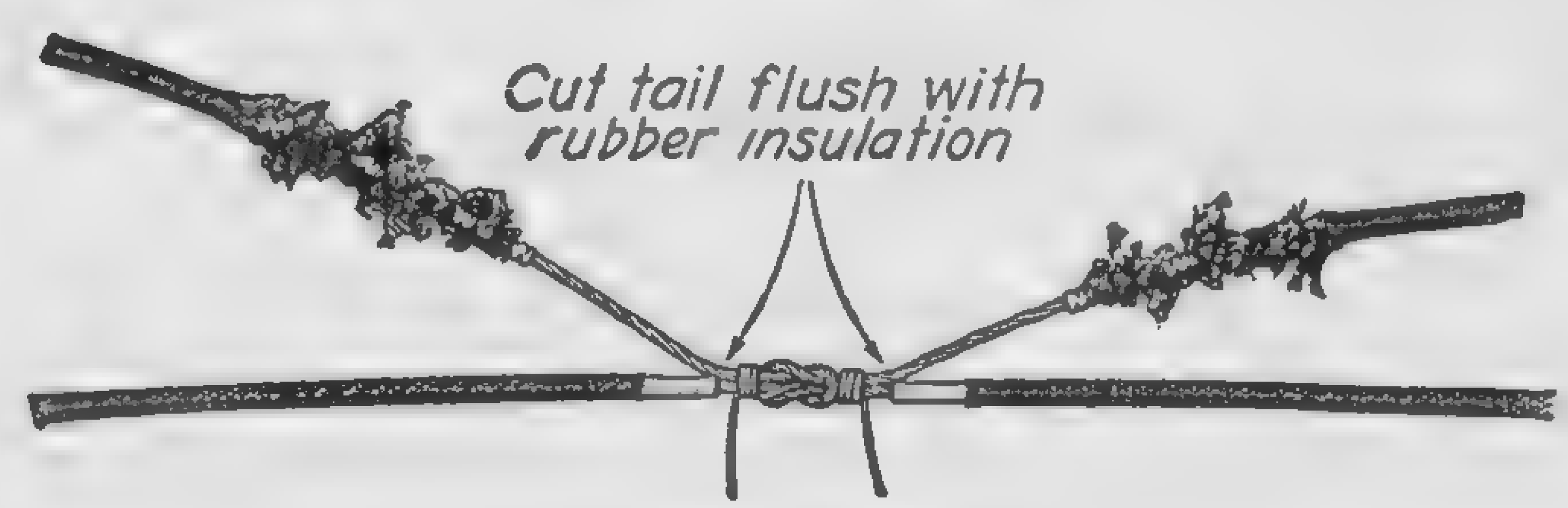



Fig. 8. Wrapping Seizing Wire

exposed rubber insulation to permit close adhesion of the rubber tape when it is applied. See Figs. 6 and 7.

*Applying Seizing Wire.* A 6- to 8-inch piece of seizing wire is inserted up through the square knot and then the knot is pulled tight, Fig. 7. The seizing wire is bent so as to have half for wrap-

ping to the left and half for wrapping to the right. Two or three close turns are taken with the seizing wire, both to the left and to the right of the square knot, Fig. 8. This is to bind the ends of the knot before cutting off the excess ends of the conductors. Now the excess ends of the conductors are cut off flush with the

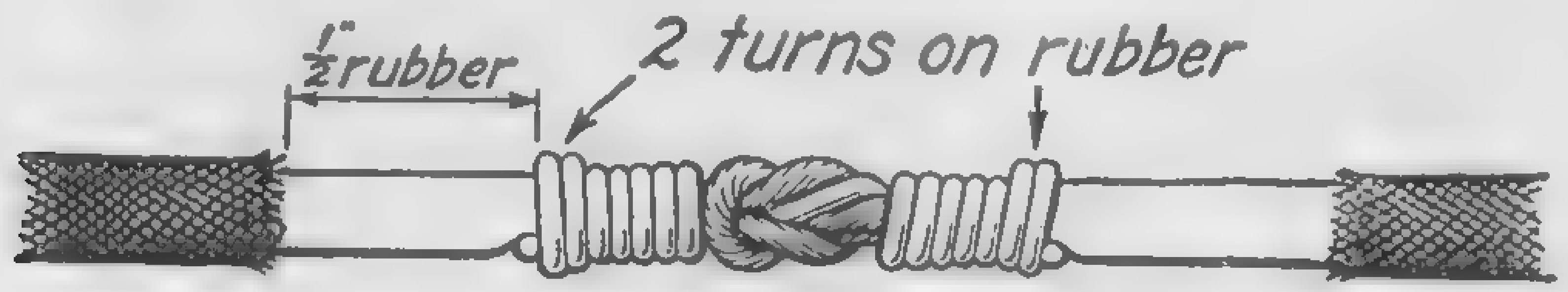



Fig. 9. Splice on One Conductor after Seizing Is Completed

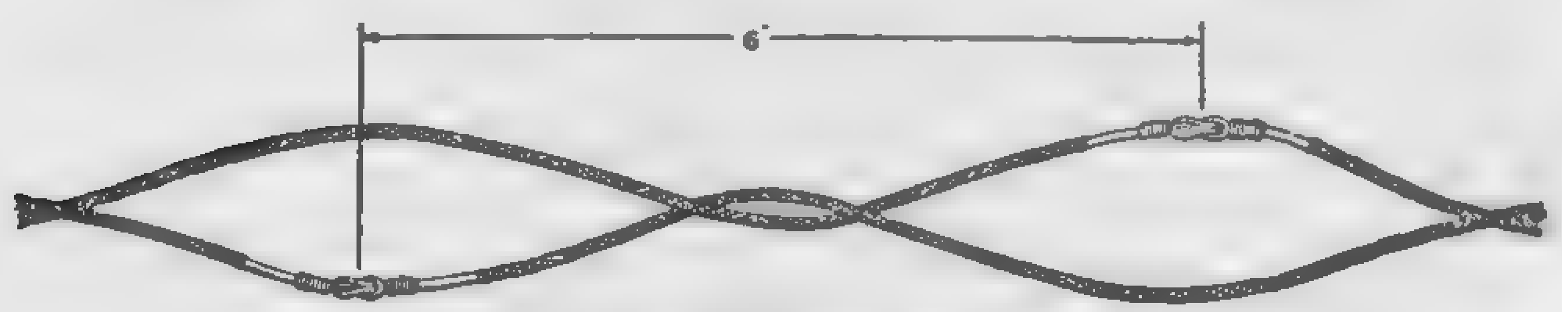



Fig. 10. Splice Ready for Taping

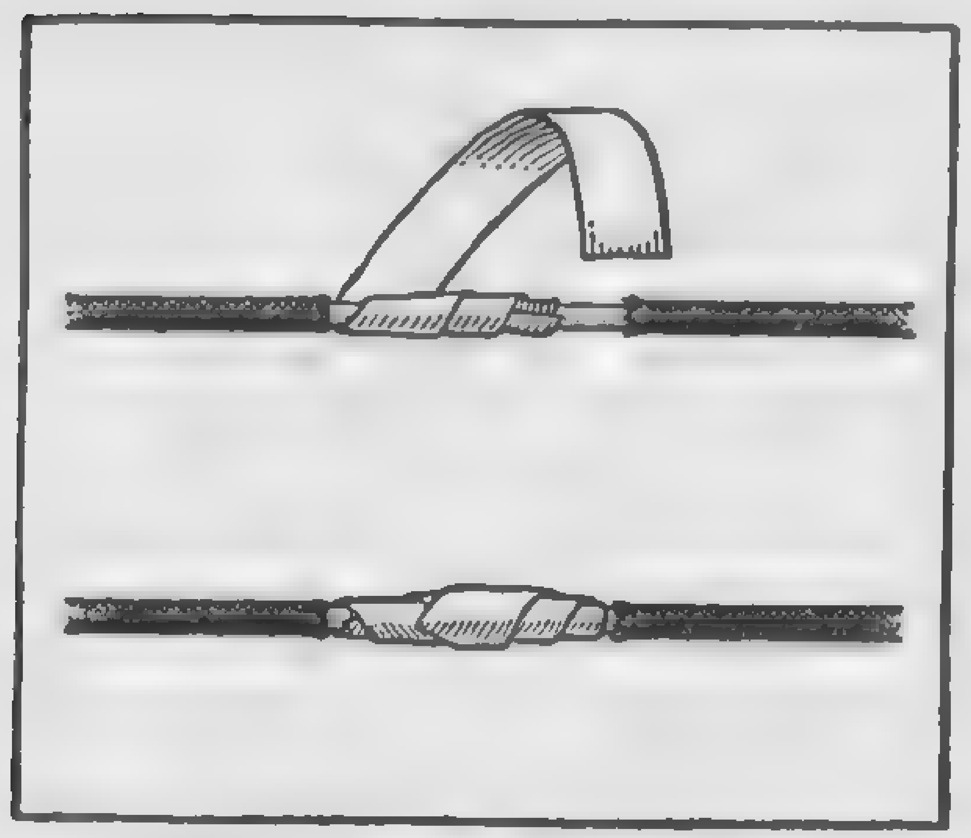


Fig. 11. Applying Rubber Tape

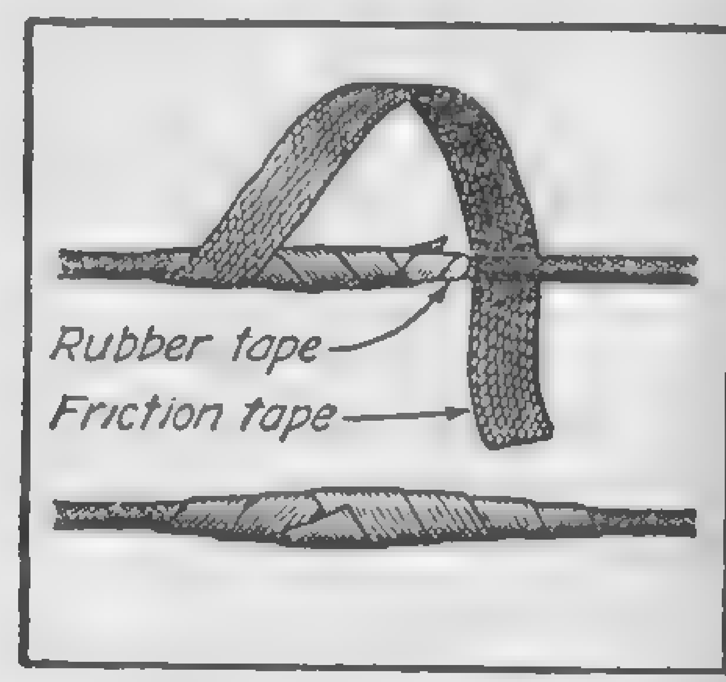



Fig. 12. Applying Friction Tape

rubber insulation. The seizing wire wrap is then continued both left and right of the square knot until two turns are taken on the rubber insulation, Fig. 9. The ends of the seizing wire are now cut off flush and pressed down into the rubber. With both men tying the square knots and applying the seizing wire at the same time, the over-all time for these operations should be about 1 minute, Fig. 10.

*Applying Rubber Tape.* For best results and ease of application, the wire is held taut when the rubber tape is being applied. One man holds the wire taut and the other applies a 4- to 5-inch





piece of rubber tape to the splice in two layers. It is started at the center of the splice and is worked to the left and right of the knot for a distance of ½ inch on the rubber insulation, Fig. 11. The rubber tape is stretched considerably so as to give close adhesion, and is pressed into intimate contact with the rubber insulation on both ends of the splice to keep the splice waterproof.

*Applying Friction Tape.* With one man holding the wire taut, the other man applies two layers of friction tape over the rubber

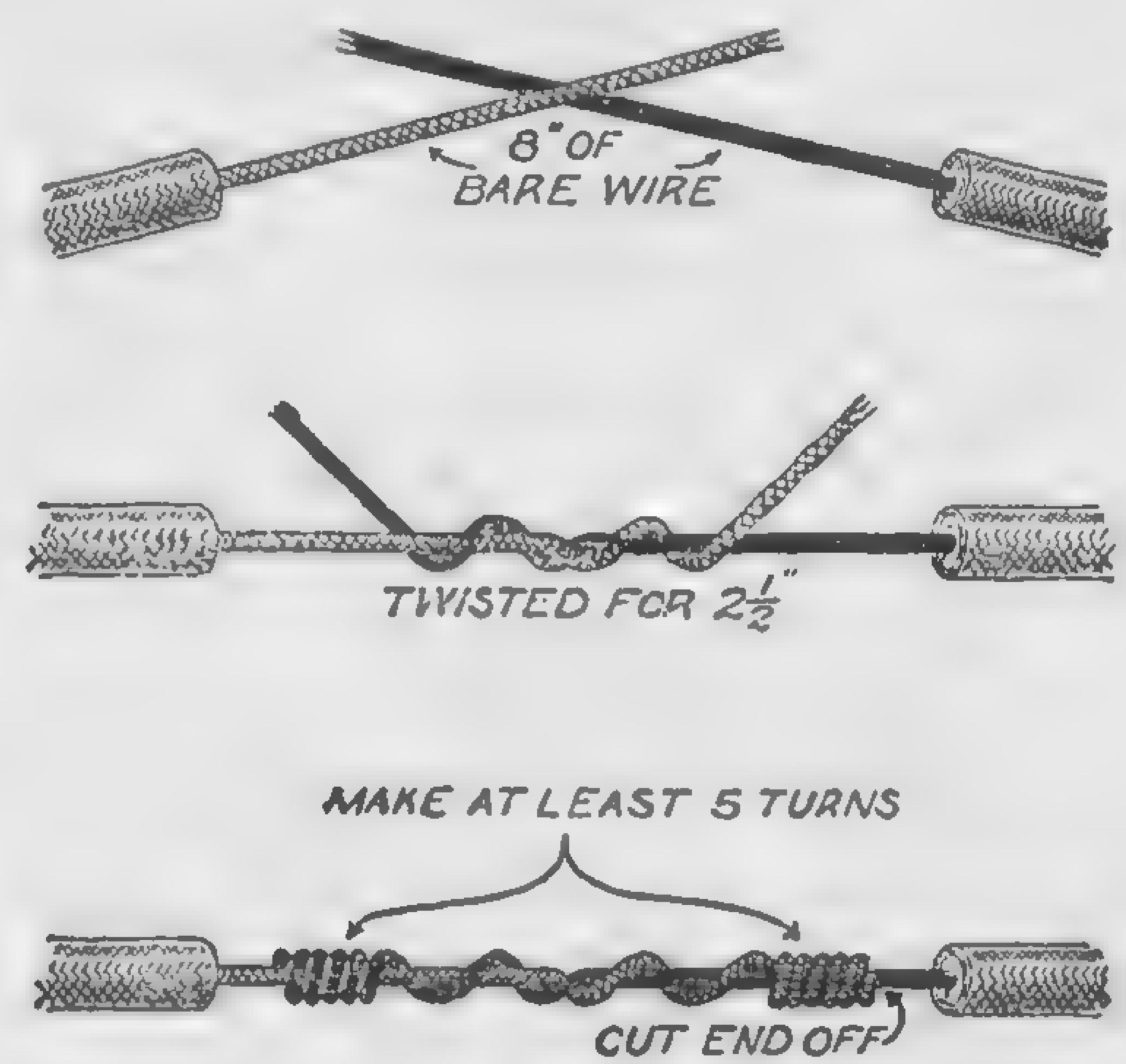



Fig. 13. Western Union Splice

tape. The friction tape is extended about 1 inch beyond the rubber tape. See Fig. 12. This gives an over-all taped splice of about 4 inches. The finished splice is then rolled several times in the hands to seal the edges of the tape.

**Western Union Splice.** (Fig. 13). The Western Union splice is used in splicing two solid-conductor insulated wires. To make the splice, strip the insulation from the end of each wire for a distance of about 8 inches and clean the wires so that they are bright and free from corrosion. Twist the bare ends together in the center for about 2½ inches. Then bend the ends at right angles to the axis of the wire and wrap each end around the wire with at least five close turns. The twisted portion of the splice is called the "neck," and the five turns at each end are called the "buttons." Cut off the ends as closely as possible, being careful

not to leave a sharp point that will puncture the tape wrapping. Directions for taping this splice and those which follow will be found under "Taping splices," the next heading.

**Combination Splice.** (Fig. 14) The combination splice is used to splice a stranded conductor insulated wire to a solid conductor insulated wire. To make the splice, strip the insulation from the end of each wire for a distance of about 6 inches and clean the

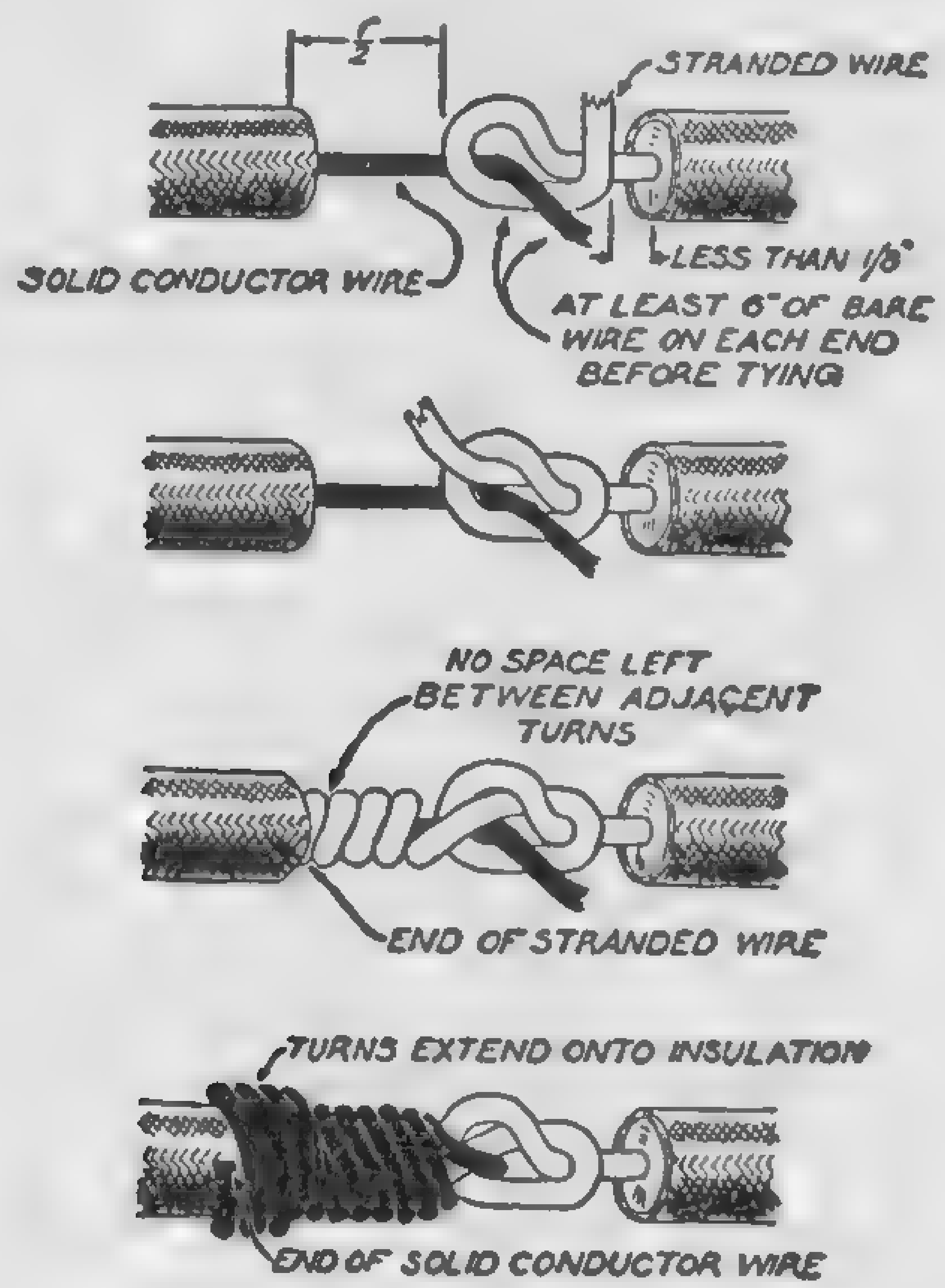


Fig. 14. Combination Splice

wires so that they are bright and free from corrosion. Tie an overhand knot in the stranded wire close to the insulation and slip it over the solid wire to within ½ inch of the insulation, Fig. 14. Pull the knot tight and wrap the end of the stranded wire around the solid wire from the knot to the insulation. Cut off the surplus stranded wire. Bend the end of the solid wire back at the knot and with it seize the stranded wire, wrapping it up as far as the insulation. Wrap the solid wire in the direction opposite to the wrappings of the stranded wire, otherwise the solid wire will fail to hold the strands in place. Continue the wrapping of the solid wire until two turns are taken over the insulation. Cut off the surplus solid wire and press the end down into the insulation.





**Combination Seizing Wire Splice.** (Fig. 15) This splice is used to splice a stranded conductor insulated wire to a solid conductor bare wire such as is used in an open wire pole line. Strip about 1 inch of insulation from the end of the stranded wire and clean both wires so that they are bright and free from corrosion. Lay this end of the stranded wire along the solid wire. Begin the seizing by taking four turns with the seizing wire around only the solid wire back of the stranded wire. Continue the wrapping, including several turns over the insulation of the stranded wire, then over the bare end of the stranded wire, and finish with four turns over

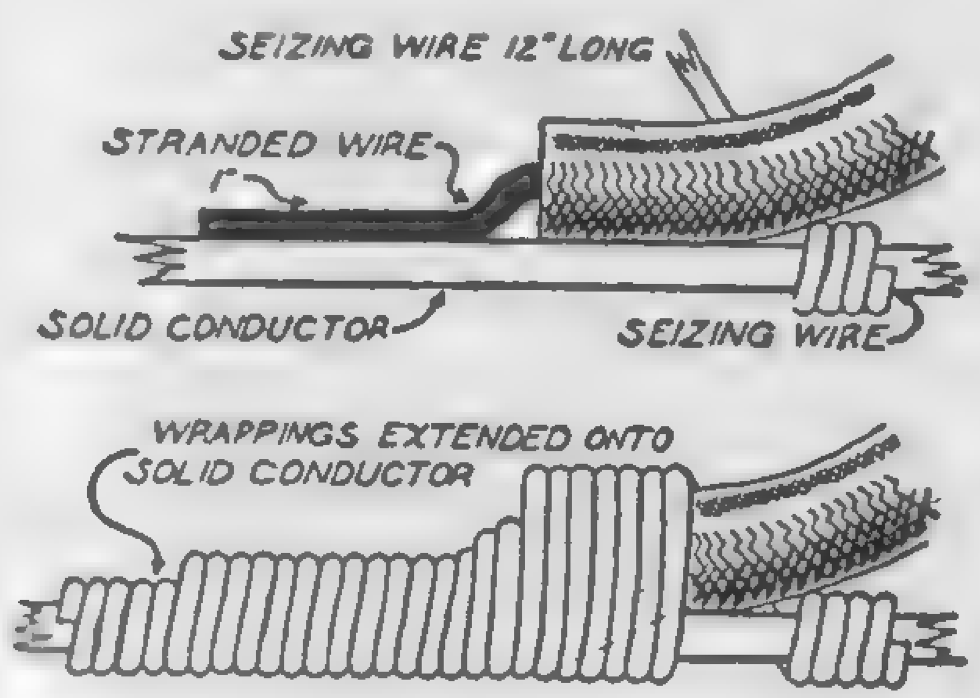


Fig. 15. Combination Seizing Wire Splice

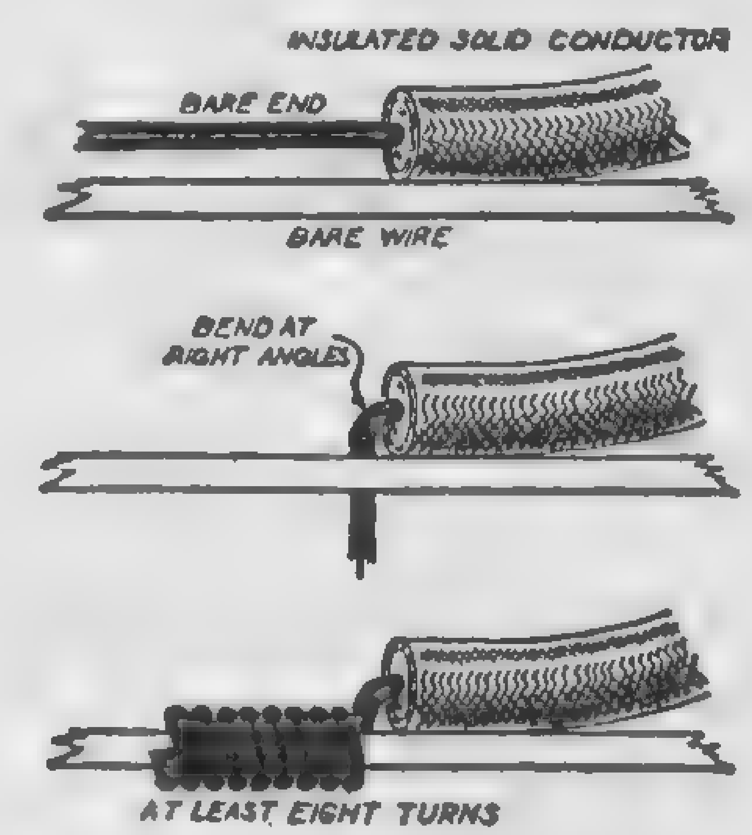


Fig. 16. Commercial Splice

the solid wire only. Wrap the seizing wire tightly and draw the turns close against each other. (See Fig. 21 for tying-in the splice.)

**Commercial Splice.** (Fig. 16) The commercial splice is used to splice a solid-conductor insulated wire to a solid-conductor bare wire such as is used on an open wire line. To make the splice, remove the insulation from the insulated wire for a distance of about 6 inches and clean both wires so that they are bright and free from corrosion. Lay this bare end of the insulated wire along the bare wire. Bend this end at right angles to the bare wire and wrap it around the bare wire for at least eight turns, drawing the turns tight and close together. Cut off the surplus end of the insulated wire.

**T-splice.** The T-splice is used to splice a wire to another without interrupting the circuit of which the latter is a part. In Fig. 17, *X* is the latter and *Y* is the former. In this illustration it is assumed that after the splice is completed the portion of *X* to the

left of the splice will be discarded and that the strain will be toward the right. To make the splice:

(1) Remove about 1½ inches of insulation from each of the conductors of $X$, 12 or more inches apart.

(2) Place $Y$ beside $X$ with the two ends at one of the bared places.

(3) Cut $Y_1$ off at the other bared place, and prepare the ends of $Y_1$ and $Y_2$ for splicing as was described under *Crushing Insulation* and *Skinning Conductor* for the *Field Wire Splice.*

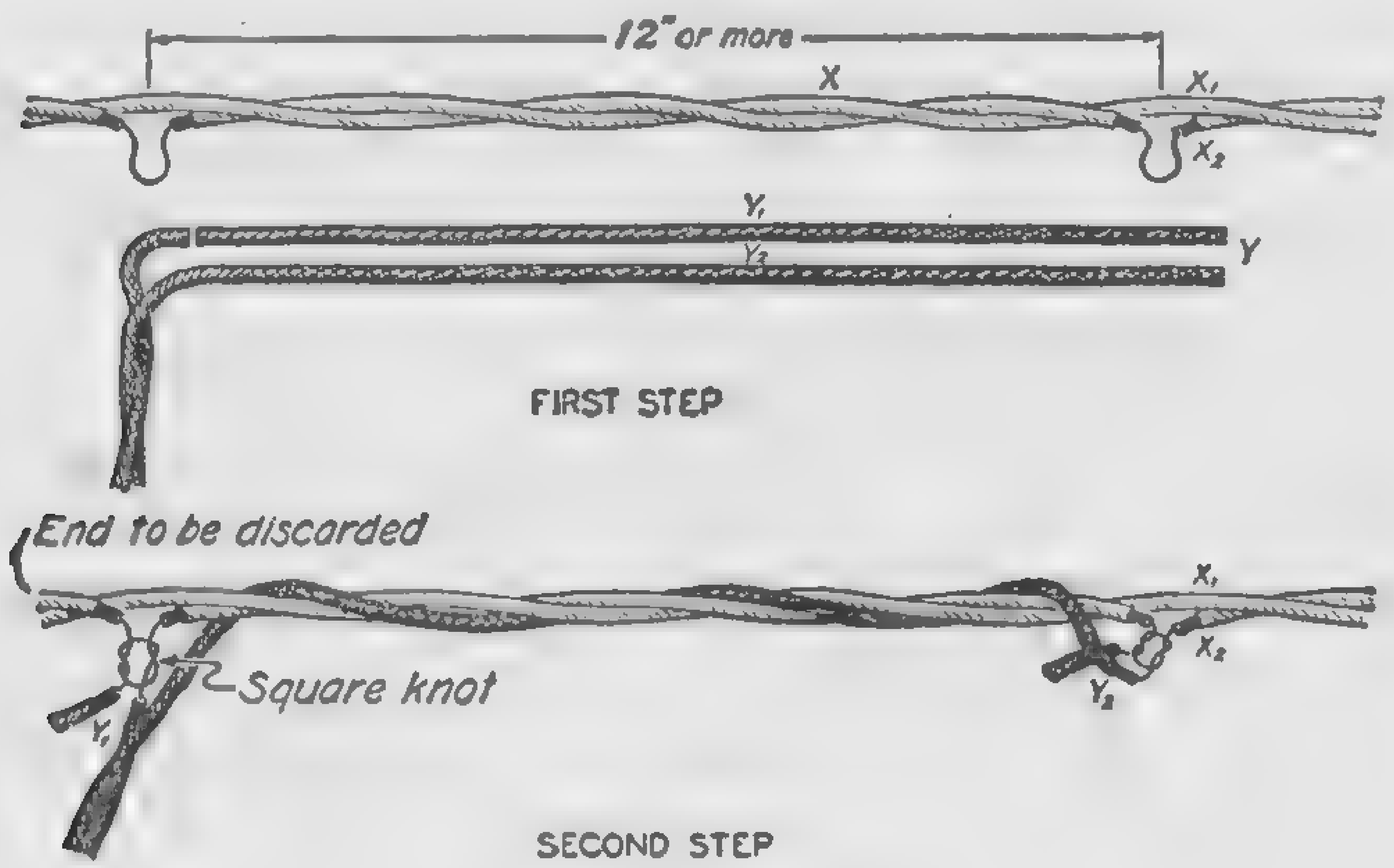



Fig. 17. T-splice

(4) Tie $Y_1$ to $X_1$ with a square knot. To tie this knot, make a loop with the left hand in the bared portion of $X_1$; with the right hand, pass the end of $Y_1$ up through the loop, over the right side of the loop, under the neck of the loop over the left side of the loop, and down through the loop; draw the knot tight. To avoid making a thief knot, be sure that the two conductors on which the strain is to be placed are on the same side of the loop, otherwise the knot will not hold.

(5) Twist $Y_2$ around $X_1$ and $X_2$, and tie $Y_2$ to $X_2$, similarly.

(6) Cut off the portion of $X$ to be discarded and complete the splice as indicated and described for Figs. 8 to 11.

## TAPING SPLICES

**a.** See description for Figs. 11 and 12 for taping the Field Wire Splice. Other splices in insulated wire (see *Western Union, Com-*





*bination,* and *T-splice*) are wrapped first with two layers of rubber tape and then with two layers of friction tape. In order that the completed splice will be well insulated it is important that the rubber tape make intimate contact with the rubber insulation on each side of the splice. This is done by removing or pushing back the braid (covering the rubber insulation) for a short distance on each side of the splice and scraping the rubber so that a clean surface is obtained to which the rubber tape will adhere closely. The rubber tape wrapping begins and ends at the center of the splice and extends over the rubber insulation for a distance of ½ inch. (See Fig. 11.) The rubber tape is stretched tightly in wrapping and pressed into close contact with the rubber insulation. Next the splice is wrapped with two layers of friction tape. The friction tape wrapping begins and ends at the center of the splice

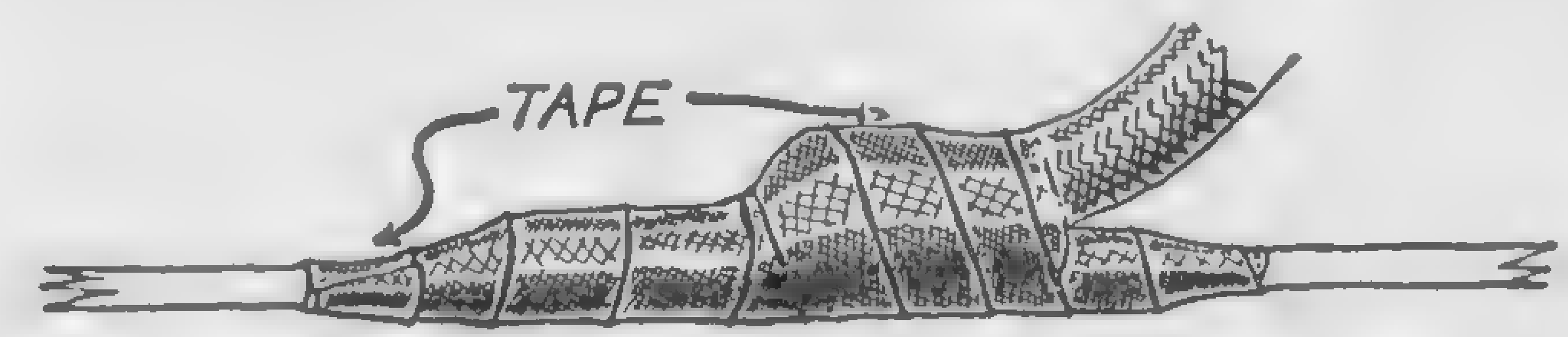



Fig. 18. Taping an Insulated Conductor Spliced to Bare Wire

and extends over the braid of each wire for a distance of one inch. The tape is drawn tightly against the braid, particularly at the ends, to make the splice as waterproof as possible. (See Fig. 12.)

**b.** When insulated wire is spliced to a bare wire, the splice is wrapped with two layers of friction tape to assist in holding the wire firmly in place. The insulated wire is brought out between the wrappings of the tape which goes beyond it. (See Fig. 18.)

## WIRE TIES

Field wire lines usually terminate at the binding posts of a terminal strip or an instrument. Obviously, any strain placed on the wire tends to pull it away from the binding posts. To avoid this, the wire is securely fastened to a convenient tree, pole, or other support before connecting it to the binding posts. Wire lines are also tied in at various points along the route where it is necessary to hold the wire in place. The kind of tie used to secure field wire to any object depends upon the nature of the object; several kinds of ties are described which should meet all conditions

in field wire line construction. Where the wire is tied above equipment to which it is to be connected, such as a telephone or terminal strip, a drip loop is made in the wire. To make a drip loop, bend the wire in the slack part between the tie and the connection

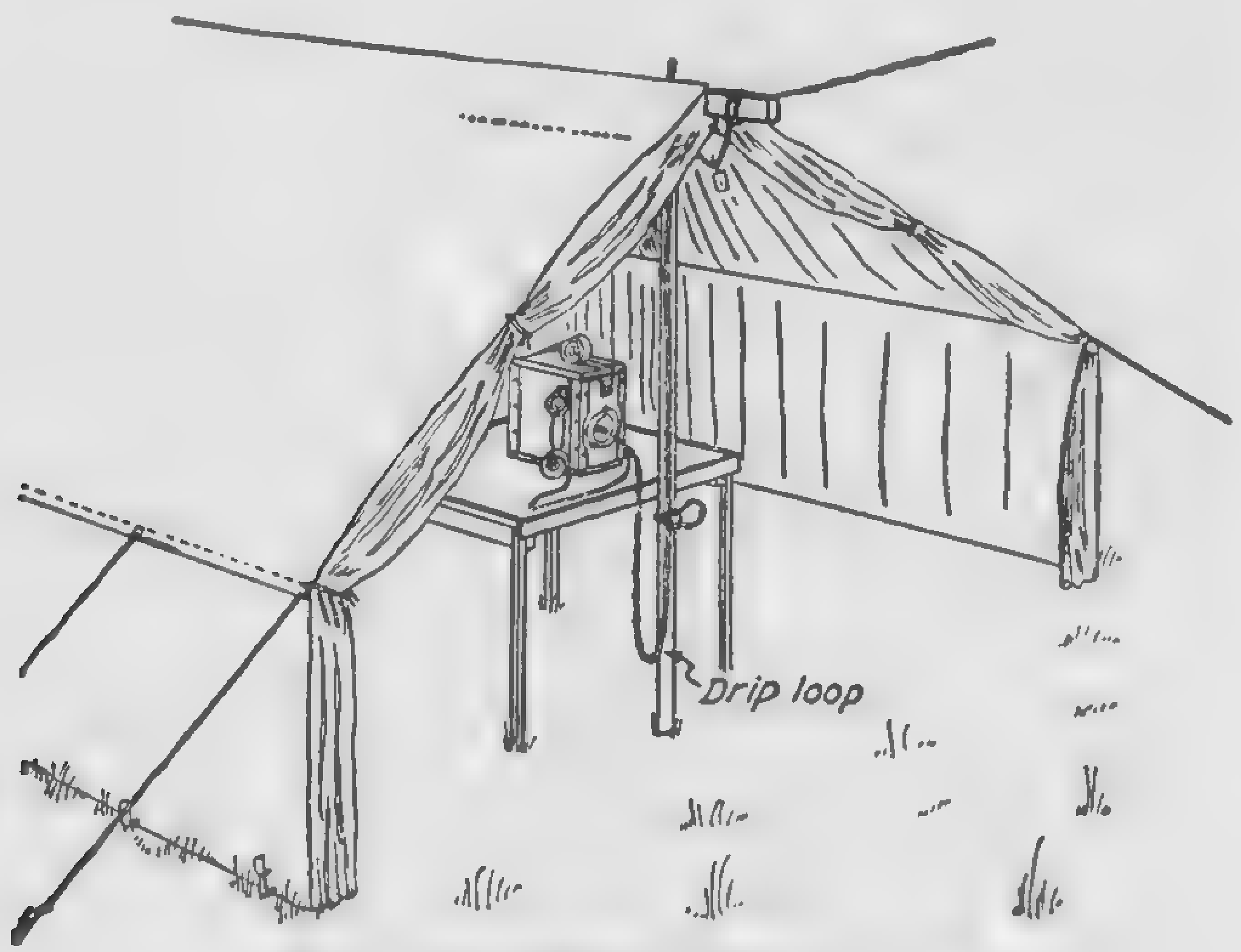



Fig. 19. Field Telephone Installed in a Tent

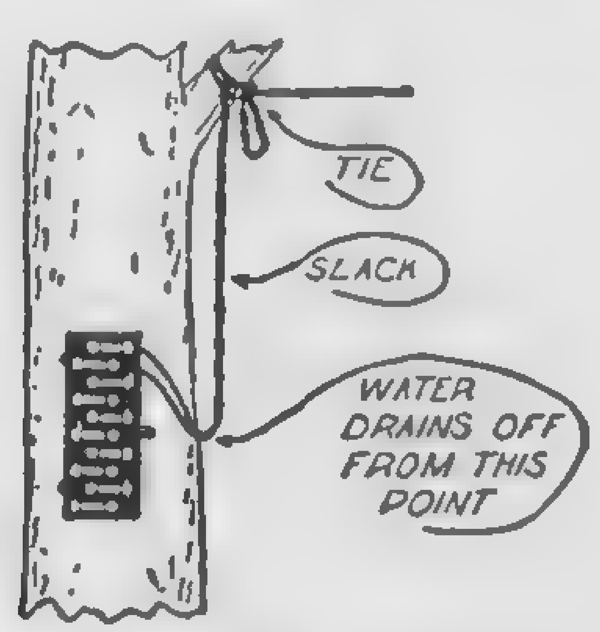



Fig. 20. Drip Loop in Wire Leading to a Terminal Strip

downward into a hanging loop. (See Figs. 19 and 20.) Water running down the wire will drip off from the bottom of the loop and will not be led to the terminal strip or instrument where it might cause a short circuit or damage to the equipment.

**Tying-in Field Wire to Open Wire.** (Fig. 21) Stranded wire is normally spliced to solid conductor wire only where it is necessary to connect a field wire to an open-wire pole line. In this case, the stranded wire is tied in to the cross arm or pole, but never





to the metal brace, near the point where the splice is to be made, and a little slack is left between the tie and the splice. The tie should take the strain, since the splice is not strong enough to withstand a heavy pull.

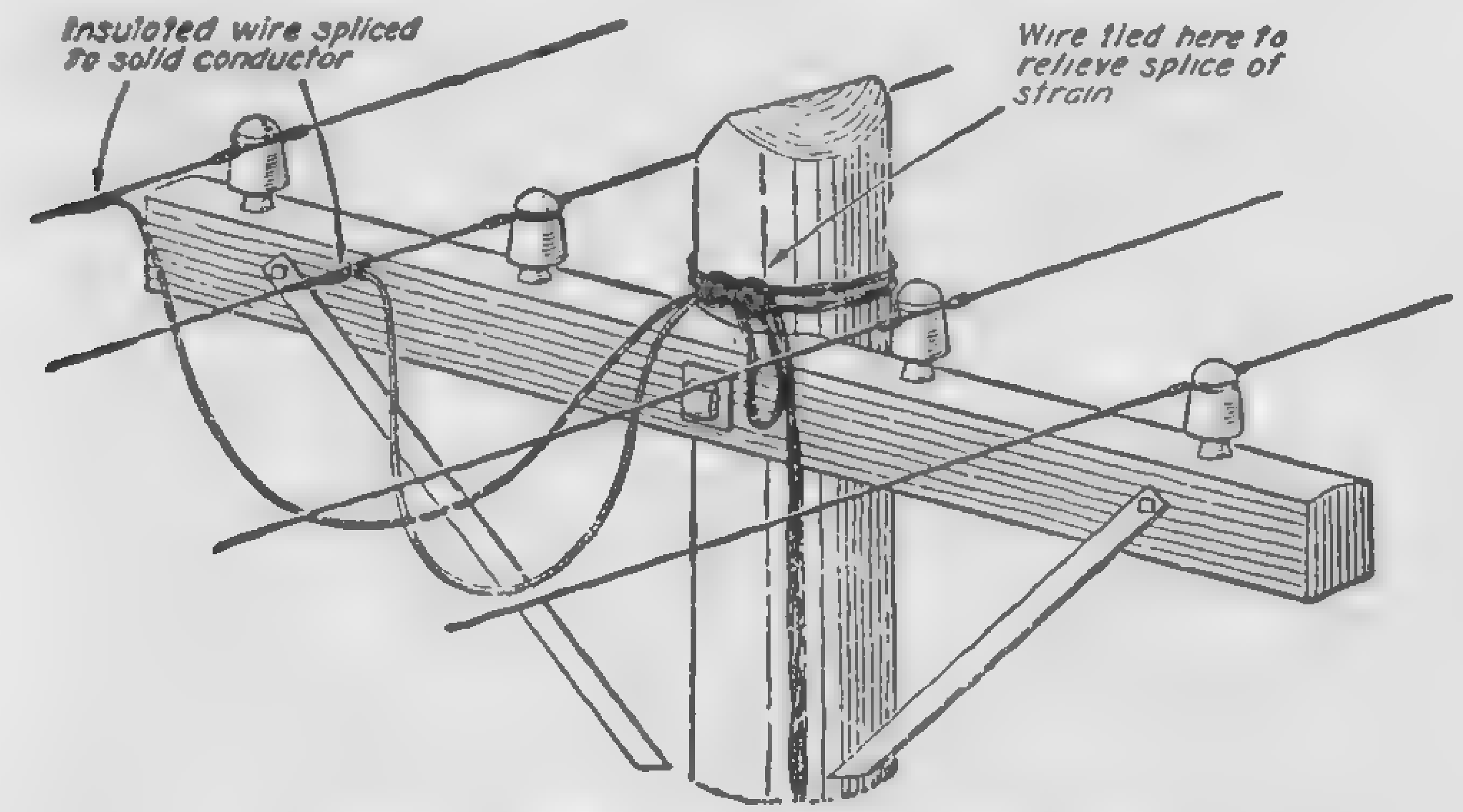



Fig. 21. Tying-in Field Wire to Open Wire

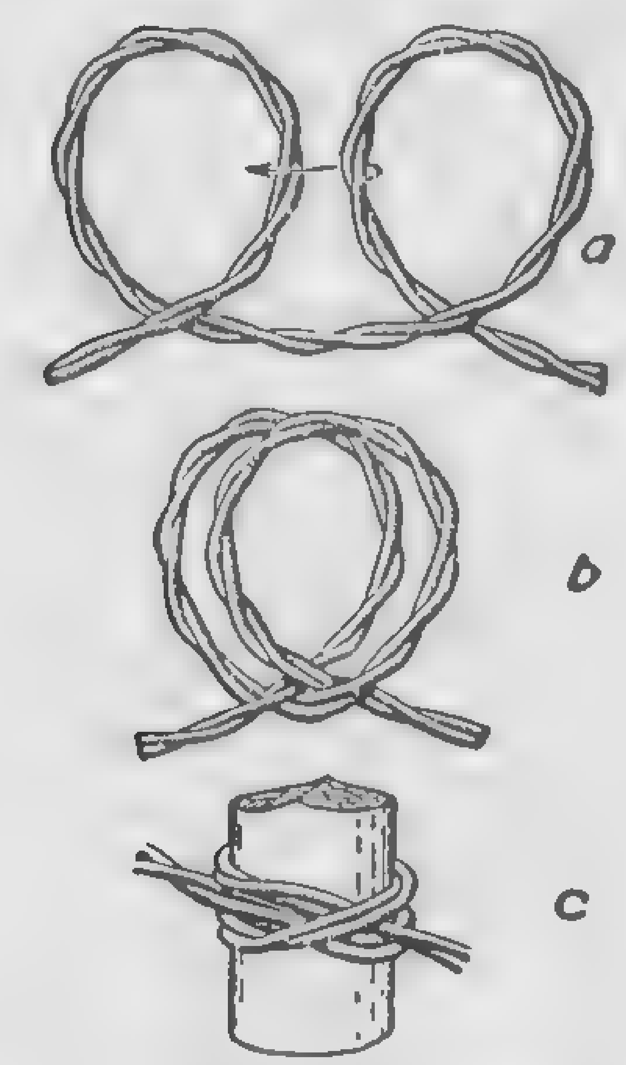



Fig. 22. Clove Hitch Tie Around a Stake

**Clove Hitch Tie.** When the end of the object to which the wire is to be tied is exposed so that the wire may be placed over it, the clove hitch tie is used. To make the tie, make two loops in the wire as shown in Fig. 22 at *a*. Place the right-hand loop on top of the left-hand loop without turning either loop, as shown in Fig. 22 at *b*. Place both loops over the object to which the tie is to be made and pull them tight as shown in Fig. 22 at *c*.

**Other Knot Ties.** When the end of the object to which the wire is to be tied is not exposed, one of the three ties described in the following is used. All three permit tying the wire without cutting it. For simplicity, Figs. 23 and 24 show only one of the two

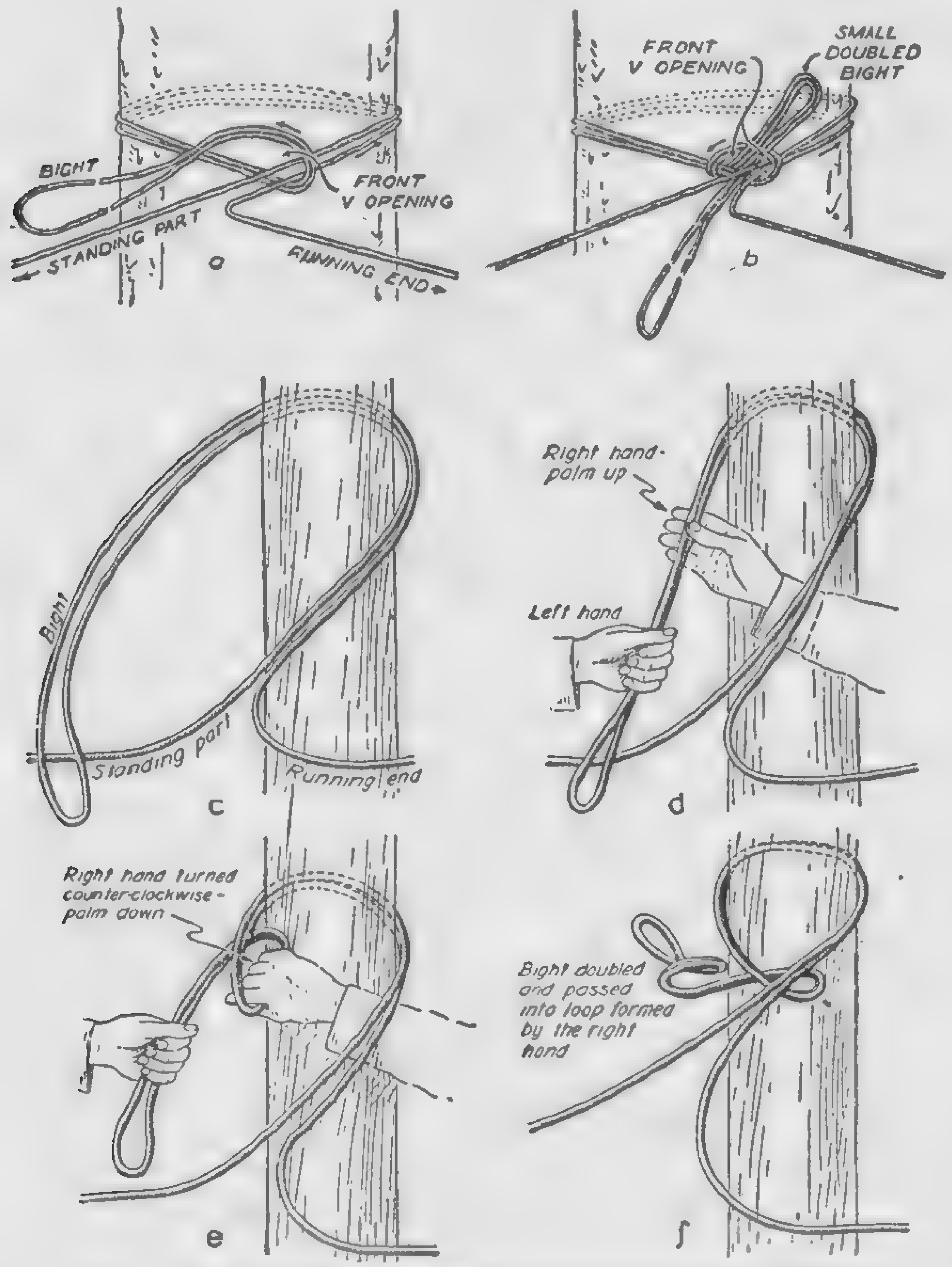



Fig. 23. Loop Knot Ties Showing only One of the Two Conductors

conductors of the field wire. In each of those figures the standing part is the portion of the line which has already been laid, and the running end is the portion leading to the wire-laying equipment. A bight is a loop formed on the wire so that the two parts of the loop lie alongside of one another.

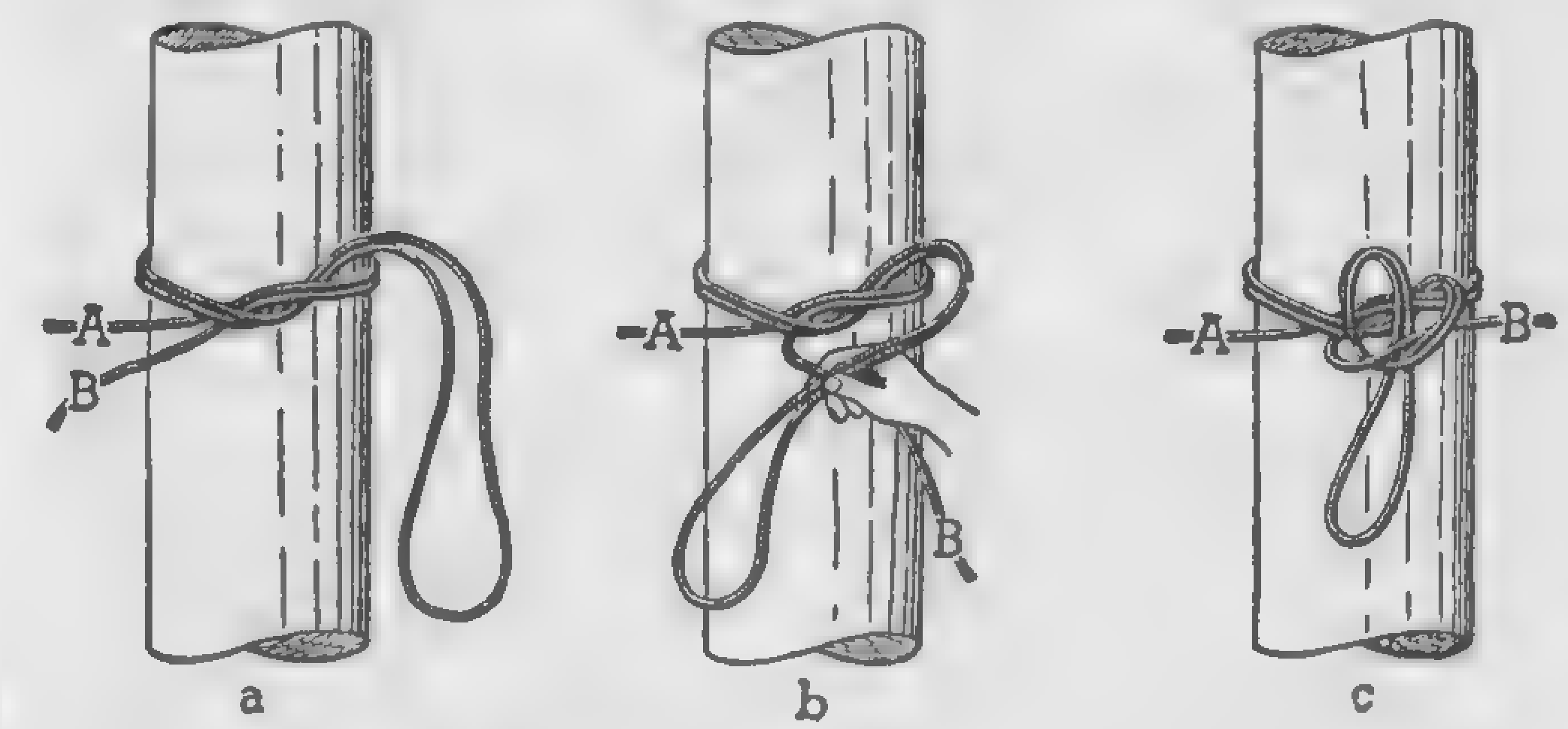
*Loop Knot Tie.* This tie is more easily and quickly made than the other two, but it is not as secure. Consequently, it is not used in





very long spans, at overhead crossings where increasing sag resulting from slipping of the tie might endanger traffic, or where it might be untied accidentally by passing personnel, vehicles, or animals.

1. To make the tie, stand facing the object on the side on which the wire is being laid. Pull in enough slack to make a bight to go around the object with about 2 feet of bight left over. If, during tying, the greater strain is on the standing part, place the bight around the object from the front, going around the side toward which the wire is being laid, and returning to the front on the




A·Standing part
B·Running end

Fig. 24. Square Knot and Loop Tie, Showing only One of the Two Conductors

side from which the wire has been laid. If the greater strain is on the running end, place the bight around the object from the front in the opposite direction. Bring the bight under and then over both the standing part and the running end, forming the front **V** opening shown in Fig. 23. Reach through this opening and pull through it about 6 inches of the doubled bight as shown in Fig. 23 at *b*. Tighten the tie, being sure that it rests against the object.

2. An alternate satisfactory loop knot tie may also be made as follows (Fig. 23 at *c, d, e,* and *f*): After placing the bight around the object as in the tie just described, hold the bight in the left hand, passing the right hand under the standing part and running end, and grasping the bight with the right hand, palm up; turn the hand in a counterclockwise direction, pulling the loop under the standing part and running end; double the bight and pass


Fig. 25. Method of Tying Wire at Ground Level: (*a*) Correct; (*b*) Incorrect


Fig. 26. Method of Tying Wire Along Curve in Road

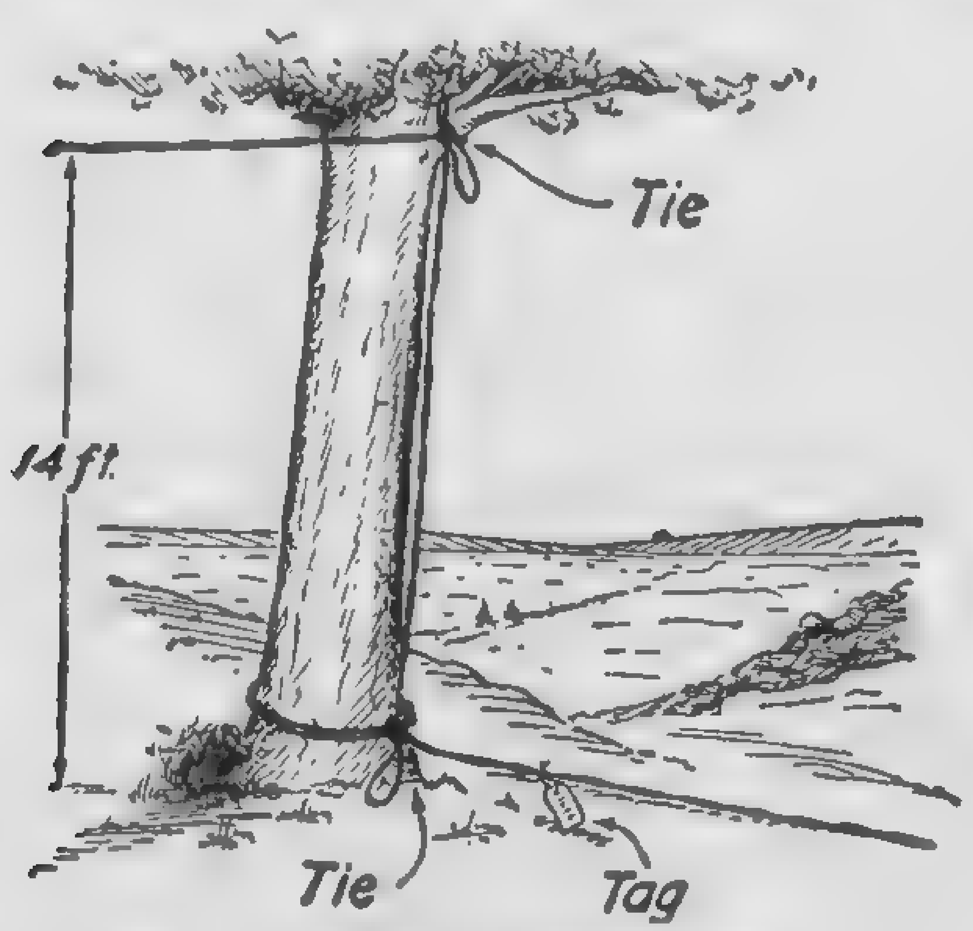



Fig. 27. Junction of Surface Line with Overhead Construction





it over the line and into the loop, pulling the bight until the knot is tight and against the object.

To untie the tie, pull the free end of the bight through the opening. The wire will fall away from the object.

*Square Knot and Loop Tie.* This tie is used in long spans, at overhead crossings, and when a tie is desired which will remain secure for a longer time than will the Loop Knot Tie.

To make the tie, begin as in *1* of the Loop Knot Tie, but bring the bight over both the standing part and the running end, and then between the object and the turn around it, as shown in Fig. 24 at *a*. Draw this knot up tightly against the object. Bring the bight over the running end, forming the opening shown in Fig. 24 at *b*. Reach through this opening and pull through it about 6 inches of the doubled bight as shown in Fig. 24 at *c*. Tighten the tie by holding the doubled bight in one hand and pulling the running end with the other.

To untie the tie, pull the free end of the bight through the opening and then untie the bight from the object. The wire will fall away from the object.

*Square Knot Tie.* This tie is used when a tie is desired which will remain secure for a longer time than those just described.

To make the tie, proceed as for the Square Knot and Loop Tie, but pull the end of the bight through the opening and tighten it by holding the end of the bight in one hand and pulling the running end with the other. It is shown in Fig. 25.

To untie the tie, reverse the procedure. After it has remained in place for some time under a strain, it is more difficult to untie than are the Loop Knot and Square Knot and Loop ties described.

Figs. 26 and 27 show how these ties are used.

**Knob Tie.** Fig. 28. These are used to tie field wire to a knob or insulator. It is not suited to tie over larger objects. To make the tie, form a loop in the wire. Separate the two conductors in the loop and bend each back around its side of the length of wire, so that they again touch each other 180° opposite the original position of the loop. Place the loop over the knob and draw it tight.

**Marline Tie.** The marline tie may be used where it is necessary to tie to a knob, crossarm, or other support. It is desirable when the object to which the wire is to be tied might damage the

insulation if the wire were tied to it otherwise. To make the tie, take a piece of marline which, when doubled, will reach from the wire in its suspended position, twice around the support, and down

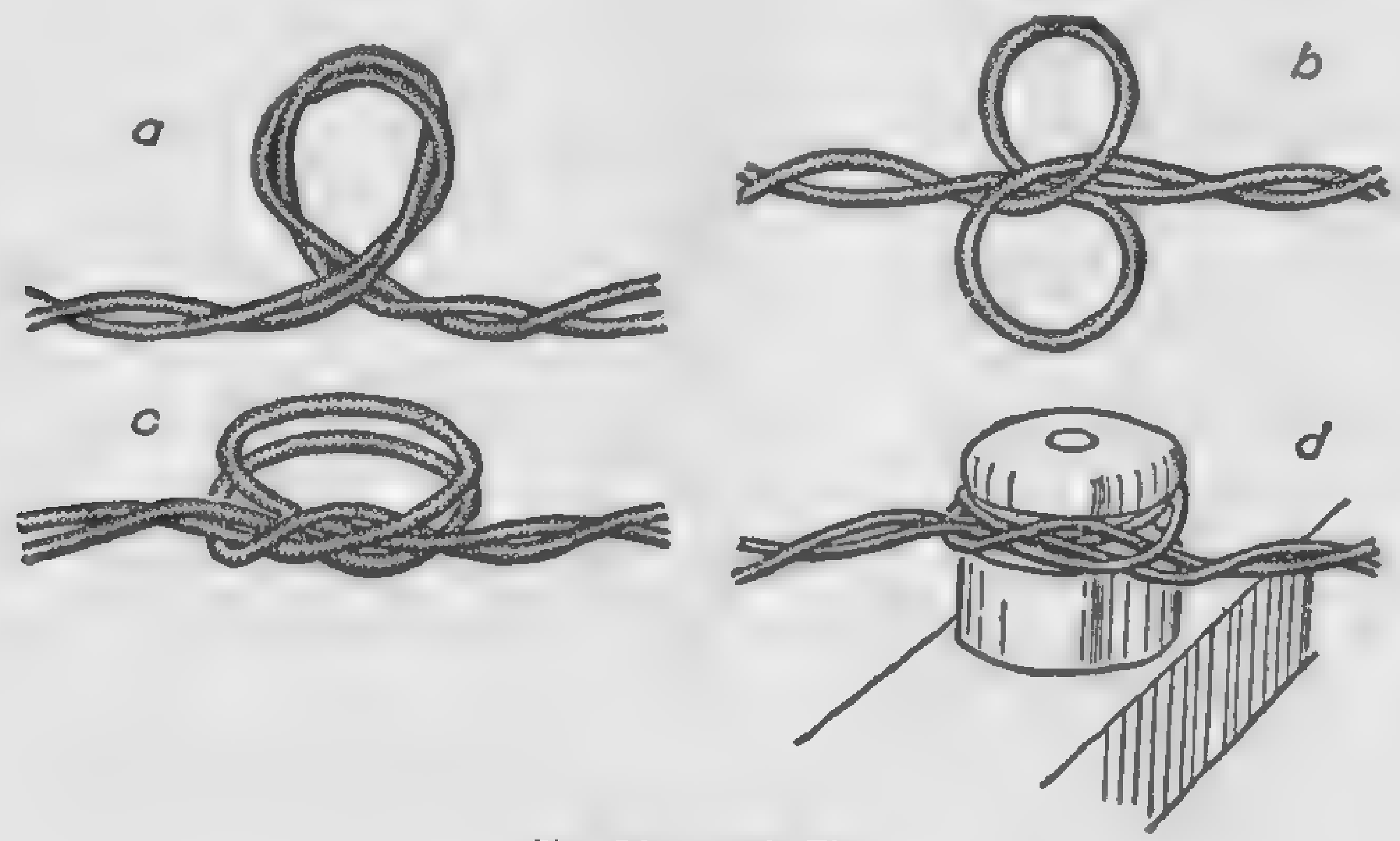



Fig. 28. Knob Tie

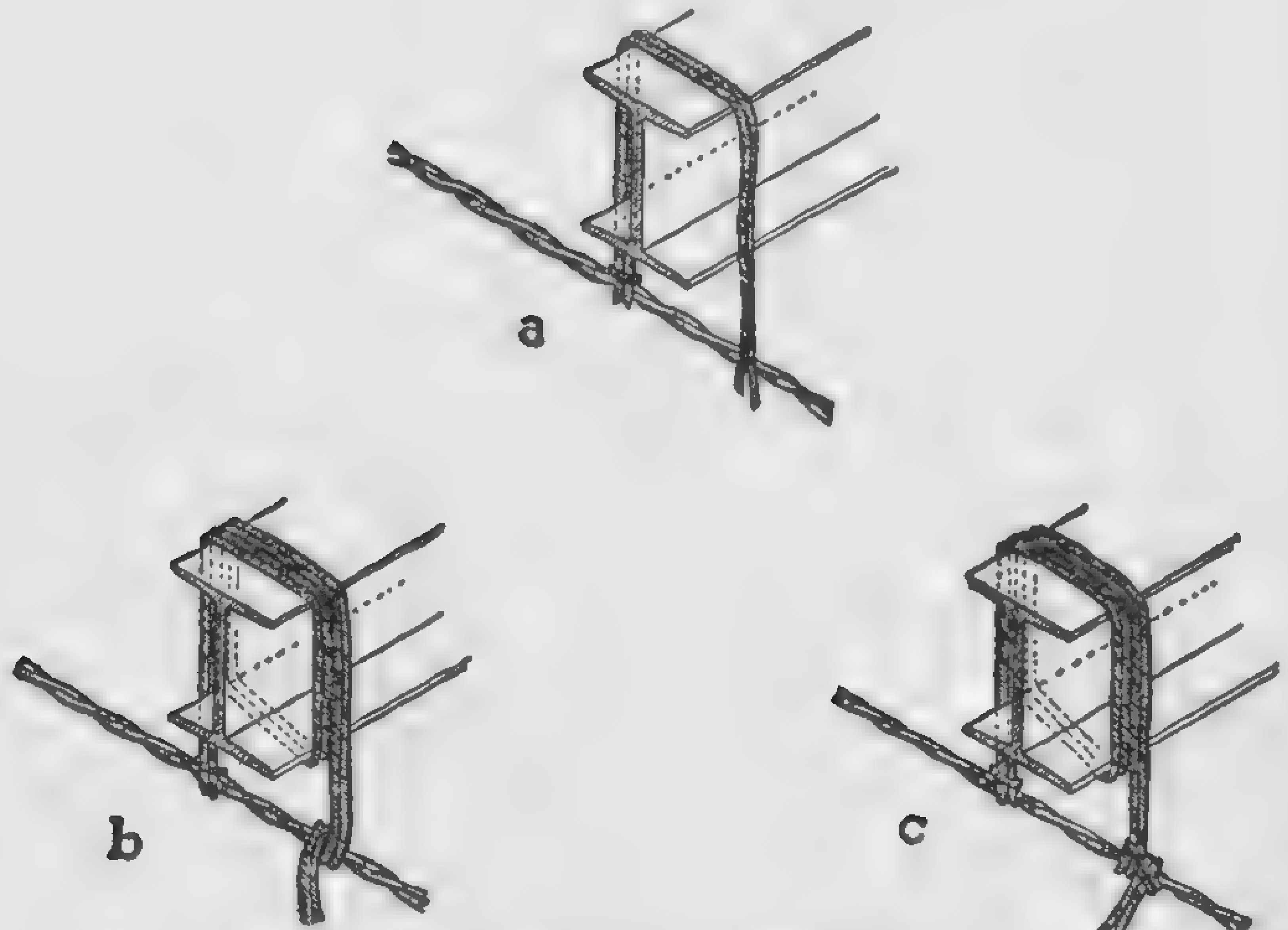



Fig. 29. Marline Tie to a Metal Support

to the wire again, with about 4 inches left over for tying. Insert the ends through the loop formed in the middle of the marline and draw the marline tight around the wire as shown in Fig. 29 at *a*. Pass the doubled marline twice around the support and back to the wire as shown in Fig. 29 at *b*. Tie it securely to the wire with a double overhand knot. To tie this knot, place the marline





around the wire and pass the running ends over the standing part to form a loop. Then pass the running ends down through this loop as shown in Fig. 29 at *c*. Draw the knot tight.

## CIRCUIT MARKING TAGS

A field wire circuit is identified by means of a designation appearing on a tag tied to the wire. The tag should be of rope stock or other fairly waterproof substance which will show the marks made by a soft pencil or crayon. A short length of soft iron wire is fastened to one end of the tag for attaching to the circuit wire. (See Figs. 26, 27, and 30). The tag is fastened to the wire about a foot from where the wire is connected to an instrument or terminal strip. Tags are also required at frequent intervals along the wire, particularly where circuits parallel each other for a long distance, at points where some circuits leave the main route, and at points where the type of construction changes, as from surface to overhead. Trunk circuits are tagged with the complete designation of the circuit. Local telephone circuits are tagged with the local telephone number. Telegraph legs are tagged with their local number and the unit to which they lead, as *TG-1 to 1st Brig., TG-2 to 2d Brig.*, etc.

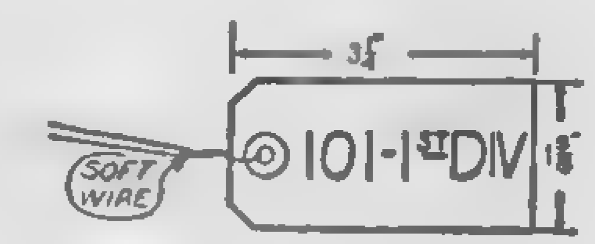



Fig. 30. Circuit Marking Tag

## TERMINAL STRIPS

**Description.** A terminal strip is a block of insulating material to which are fastened a number of binding posts. The binding posts are connected in pairs by metal strips, so that a wire connected to a binding post on one side will be joined electrically to another wire that is connected to the corresponding binding post on the opposite side. The type commonly used for field wire systems is the terminal strip *TM-84-A* which will handle five pairs of wire. See Fig. 31.

**Connecting a Wire to a Terminal Strip.** (Fig. 32) To make the connection, skin off about ½ inch of insulation from the end of the wire to be connected. Open the slot in the binding post to its fullest extent by unscrewing the knob with the fingers. Insert the end of the wire into the slot so that it projects through the binding post. As an alternative satisfactory method, skin off about 1 inch of insulation from the wire, leaving about 1 inch of insulation on the end, double the bared portion, and insert it into the slot. Tighten the knob firmly with the fingers, clamping the wire securely in the slot so that a good electrical contact is secured. Do not use pliers to tighten the knob as the threads on the binding post may become stripped.

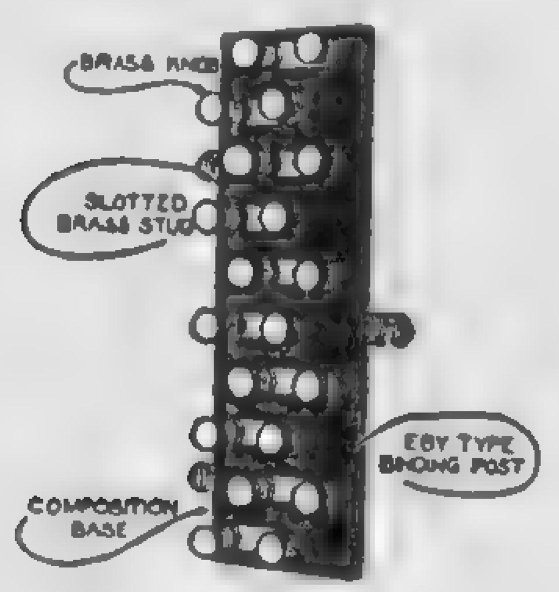



Fig. 31. Terminal Strip TM-84-A

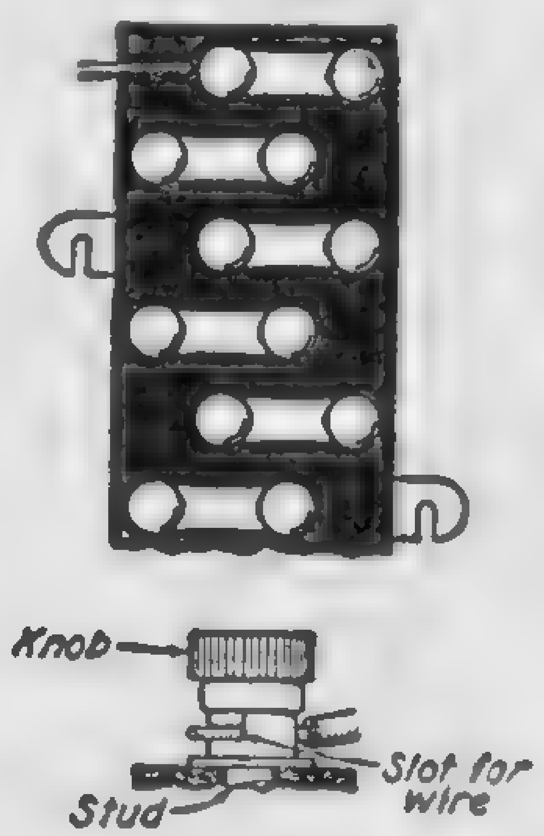



Fig. 32. Wire Connected to Terminal Strip TM-84-A

## SOLDERING

Soldering is the binding together of two or more metals by means of a fusible alloy of tin and lead called solder. The solder used in the operation must melt at a lower temperature than the metals being joined together. However, the nearer the melting points of the solder and the soldered metals, the stronger the completed joint.

**Fluxes.** When a metal is heated, its surface combines with the oxygen of the air, forming a substance called oxide. A flux is used to prevent this oxide from forming when soldering. If a flux were not used, it would be impossible to solder a joint. Rust on a piece of iron is a kind of oxide.





There are two classes of fluxes, *corrosive* and *noncorrosive*. A corrosive flux is used when soldering galvanized iron, zinc, iron and steel. Borax, sal ammoniac and zinc chloride are corrosive fluxes. A corrosive flux should seldom be used in electrical work, as it eats away the metal being soldered. After using a corrosive flux, the joint must be thoroughly cleaned to remove traces of the flux left on it, thus preventing the flux from eating away any more of the material. Stearine, rosin, and tallow are noncorrosive fluxes. These are used when soldering copper, lead, tin, etc. A noncorrosive flux prevents and cleans the oxide when soldering, without eating away any of the material. Rosin is the most common noncorrosive flux. It may be in the form of a powder, a liquid, or a paste.

A flux, to have a cleansing effect on a surface, must melt at or below the fusing point of the solder and must prevent any oxidation by excluding the air during the process of soldering. Different substances solder better with different fluxes, although rosin is the best all round flux for general use. The usual fluxes for common metals are as follows:

| | |
|---|---|
| Noncorrosive | |
| Aluminum | Stearine |
| Brass | Rosin |
| Copper | Rosin |
| Lead | Rosin, tallow, or Stearine |
| Tin | Rosin |
| Corrosive | |
| Iron or steel | Borax or sal ammoniac |
| Zinc | Zinc chloride |
| Galvanized iron | Zinc chloride |

**Solder.** Solders are divided into two general classes, hard and soft. Hard solders are usually used in brazing. They are composed of silver and its alloys or other compositions of the harder metals, and have a high melting point. Soft solders are used for general soldering and electrical work. They are composed of lead and tin. The types of soft solders usually encountered in the Signal Corps are: a bar composed of 50 parts tin and 50 parts lead used for general soldering work; and a wire solder with a rosin

core, which is very convenient to use when soldering small terminals, lugs, and radio or telephone parts.

**Soldering Irons.** The heat for soldering is generally supplied by a soldering copper, commonly called *soldering iron.* The soldering iron consists of a copper bit fitted with a suitable shank and handle. The bit of the soldering iron is made of copper, because copper has a high thermal conductivity and readily permits the heat to flow from the body of the copper to its tip. In addition, copper tins readily. Coppers of different size are used for different kinds of work and are classified according to their weight.

Soldering irons are heated either *externally* or *internally.* The externally heated iron is heated by a gasoline blowtorch or a gasoline furnace. The internally heated, or electric iron, is heated by an electric heating element in the shank of the iron. The electric iron has two great advantages over the torch-heated iron. First, it is easier to keep hot while in use. Second, it is easier to keep from overheating. Overheating an iron oxidizes the tinned surface, thus preventing the even flow of solder over the copper surface. Overheating also causes the copper to become rough and pitted. To solder efficiently, the point of the soldering copper must be clean. To free the iron of tarnish and oxide, the point is covered with a thin coat of solder. This process is called tinning. The tinning is usually done on a soft brick, with a part of the top hollowed out. To tin the iron, proceed as follows:

1. Place a small amount of powdered rosin on one end of the brick and some scrap solder on the other end. Heat the iron with the blowtorch.

2. File one side of the iron, immediately turn it over and rub the filed side first in the rosin and then in the solder. Wipe the excess solder from the point with a clean rag.

3. Continue filing and tinning each side in succession until all four sides are tinned.

4. The iron must not be too hot for the best results. If it is too hot, the solder will not stick. To prevent the destruction of the tinning, when heating the iron for use, keep the point of the soldering iron from direct contact with an open flame.

5. The electric iron is tinned on one side only. File the side selected after the iron is hot and melt a small amount of





rosin core solder on the cleaned surface. Wipe off the excess solder with a clean rag.

Usually the irons are made with a removable tip. It is very important that the tip be removed from the element and that both tip and tip socket are cleaned of all scale. This *must* be done after every *thirty hours of operation.* This cleaning is done to prevent the tip from sticking in the element.

If it becomes necessary to remove the element from the iron, the following procedure should be followed:

1. Remove the tip.

2. Hold the element end of the iron in the left hand and unscrew the handle with the right hand.

3. Slide the handle back on the cord.

4. Remove the two screws that hold the flat wires which lead to the element.

5. Remove the element lock nut.

6. Slide the element case forward and off the element.

7. Remove the element by sliding it forward.

When renewing the cord of the iron, do not use any wire other than *heater cord;* that is, a cord which has a covering of asbestos on each wire.

**The Blowtorch.** The gasoline blowtorch consists of a round, brass tank, an air pump and a burner assembly. The tank is filled with gasoline through a filler plug in the bottom of the tank. On top of the tank near the handle is the air pump which keeps the fuel under pressure; also on top and near the edge of the tank is the threaded vent for the fuel supply tube. The fuel supply tube contains a wick and also supports the burner assembly. The burner assembly consists of a gas orifice, a needle control valve, a vaporizing chamber and a perforated combustion chamber. Just beneath the burner assembly is a priming cup. The procedure in lighting the torch is as follows:

1. Invert the torch and remove the filler plug. *Use drift pin.*

2. Fill the tank three-fourths full with ordinary gasoline. Do not use high-test gasoline and do not fill the tank completely full, because some space must be left for air pressure.

3. Replace the filler plug and place the torch in an upright position. In replacing the filler plug, do not use excessive force;

a little soap on the threads of the plug will help seal the container.

4. Place the fuel under pressure with the air pump. Pump until it works hard.

5. Hold palm of hand over the end of the combustion chamber and open the needle valve slightly. This allows the fuel to flow into the priming cup. Shut the needle valve when the cup is ¾ full.

6. Light the gasoline in the priming cup and keep the flame directed toward the combustion chamber.

7. Just before the fuel is completely burned out of the cup, open the needle valve. If the gas does not ignite, hold a match near the vent holes in the combustion chamber. Do not hold the match at the end of the chamber.

To increase the flame increase the pressure in the tank and adjust the needle valve. Avoid excessive pressure, because the flame cannot be controlled so well.

The purpose of burning fuel in the priming cup is to thoroughly heat the vaporizing chamber. This causes the liquid fuel to be turned into gas.

When using the torch to heat an iron, do not let the point come in direct contact with the flame. To do so will necessitate retinning the point. A blow torch is seldom cared for properly. This results in a great deal of unnecessary repair work. Some general rules for the care of the torch are given as follows:

After the priming cup has been filled, wipe any spilled gasoline from the other parts of the torch before lighting it.

When the gasoline is nearly consumed in the priming cup, do not open the needle valve fast. If the torch is not hot enough, this will cause a stream of flaming gas to leave the combustion chamber, and create a fire or burn the user seriously.

As the gasoline in the torch is consumed, more air is required. Pump the torch up occasionally.

Metal contracts and expands with changes of temperature. When closing the needle valve, shut it down tight enough to put out the flame and then turn it back a little to prevent the possibility of freezing.

**Requirements for Good Soldering.** In order to do good soldering, it is necessary that the following be observed:





The surfaces to be joined should be clean, it being impossible to make solder stick to a dirty or greasy surface.

The soldering iron should be cleaned and properly tinned.

The metals being soldered must be heated in order that the solder will adhere to the surface.

The surfaces being joined should be as close together as possible, with the least amount of solder between the surfaces. Too much solder means a poor joint.

The area of the joint being soldered should always be comparatively large to secure the necessary strength. With a properly tinned iron and the proper flux, the success of any soldering operation depends upon the cleansing of the surfaces to be joined and the heat applied to the joint during the soldering operation. The heat which is applied depends upon the speed with which the iron is drawn along the joint. If the iron is moved too slowly, the solder tends to spread too much and if moved too rapidly, the solder will not have time to melt completely and the joint will not be filled with solder. If heavy material is being soldered, the iron will have to be moved more slowly than if the metals being joined are metals whose melting point approaches that of solder. When using an extremely hot iron, the position of the iron is varied as the work progresses. When starting, the point of the iron is used. As the iron cools, it is lowered so that more of the flat tinned surface of the point is in contact with the work. This is not so important with electric irons, as the heat does not vary so greatly if the iron is properly used.

**Soldering Splices.** Half-and-half solder has an electrical conductivity of about one-seventh that of copper. All splices between conductors that are to carry current should have the smallest possible amount of solder separating conductors. This means that the wires to be joined must be as close together as possible before the solder is applied.

There are two methods of soldering a splice. The first, known as flowing, is to hold the hot iron on the top side of the splice and run the solder into the joint. The second, known as sweating, is to heat the joint from the under side while the flux and the solder are applied from the upper side. The wires melt the solder

as soon as they become hot enough, and the melted solder is drawn into the cracks between the wires. Sweating is the better method. When soldering a Western Union splice, it is soldered only in the neck and not in the buttons.

**Soldering Flat Surfaces.** When soldering two flat surfaces, such as two overlapping plates of metal, it is usually desirable to tack the two pieces together at several points by drops of solder, before attempting to solder the entire length of the seam. This will hold the two plates in position while the main soldering is being done. When soldering one flat piece of metal to another, they are usually sweated because of the difficulty in getting solder into the joint. If the surfaces to be joined are first tinned, then placed in contact with each other and heated, there is more chance that a better joint will result, than if the solder is drawn into the joint. To sweat such joints, the metals must be close together after being tinned. If the surfaces are uneven, the sweating process is not successful unless it is combined with soldering in the ordinary manner. That is, the surfaces are first tinned, placed in contact, and while being sweated, solder is applied to the edge of the seam and drawn into the joint.

**Using the Electric Iron.** The electric soldering iron is delicate in construction and requires careful handling. When soldering, do not swing or jerk the iron to remove excessive solder. This practice endangers men working nearby and may damage adjacent equipment. Do not strike the iron against a solid substance as this is likely to crack the heating element and cause a breakdown of the insulation. When the iron is not in use, always keep it in its holder.

**Soldering Large Terminals.** Wiring that terminates at power boards and other apparatus is generally sweated into terminal lugs.

Terminal lugs, especially for the larger sizes of wire, usually have a cup socket at the bottom. When soldering a solid or stranded wire into the socket, the preferable method is to tin the end of the wire and fill the socket with solder; ordinary methods, where the wire is placed in the socket and the solder heated and run into the socket with the iron, make it difficult to get the solder down in the plug. The socket is then heated in the flame of the torch in the case of large sockets, or with





the iron for small sockets. When the solder in the socket is hot, the tinned end of the wire is inserted into the socket and the source of heat removed. The wire should not be moved while the solder is cooling. After the solder has set, more solder may be worked in if the socket is not full.

**Soldering Small Terminals.** Small terminals are more easily soldered with an electric iron. When soldering wires to terminals which are mounted near a sealing compound, such as transformers, only enough heat should be applied to melt the solder. Otherwise, the sealing compound will melt and run over the work; but be sure to apply sufficient heat. Only a small amount of solder is necessary on small terminal lugs to make the required joint. The use of too much solder makes a messy and lumpy looking job. An improper joint, one which will probably cause trouble, is where the solder has sweated only to the wire, while between the wire and the lug there is a flux which acts as an insulator. A connection of this kind is due to one of the following causes: A cold soldering iron; the soldering iron held on the work an insufficient length of time; improper use of the iron; and untinned or unclean lugs and wire. The iron should be held on the lug and wire until both become hot enough to melt the solder. This is one of the fundamental rules of good soldering. A satisfactory job cannot be done if the solder is run on a cold or improperly cleaned lug, even though the iron is sufficiently hot and properly tinned.

Terminals and terminal punchings encountered in telephone work are usually small ones and are of various shapes and sizes. The word "punching" means that the kind of terminal is punched from a sheet of metal. Punched terminals are usually small and flat, though sometimes they have been shaped to give clearance and accessibility. Other terminals of a similar size are actually the ends of the contact springs of relays, lamps and jack strips, keys and switches of various types. Terminal punchings must have a mounting to hold them in place. Some are mounted separately, or in groups of two or three, by means of screws, or they may be merely stuck into the wood frame of an instrument, telephone or switchboard. The greatest number are mounted in terminal blocks. Standard terminal blocks are assem-

bled to accommodate twenty circuits, having from two to six rows of terminals with twenty terminals in each row, depending upon the purpose they are to serve. The employment of these blocks on main and intermediate distributing frames is not considered here. A single terminal punching and the end view of block in which this punching is mounted is shown in Fig. 33.

Fig. 33

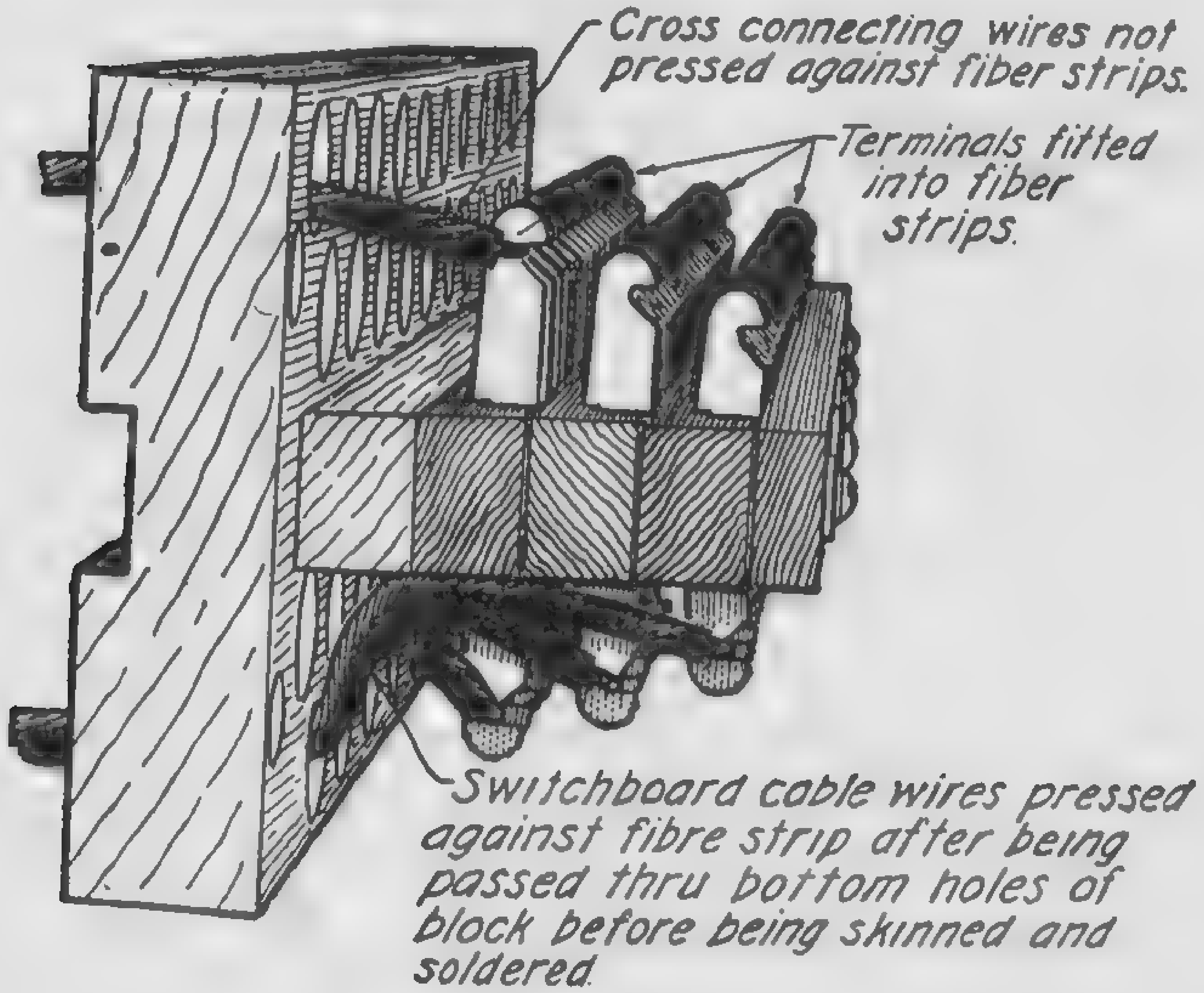



Fig. 34

An end view of a horizontally mounted terminal block is shown in Fig. 34.

*Note 1.* When blocks are mounted vertically, switchboard cable wires are brought in on the left side and under their respective terminals.

*Note 2.* Wires are skinned, and scraped of enamel so that the insulation comes up to, but not in, the notch or hole of a notched or drilled terminal.

Types of improperly soldered connections are shown in Fig. 35.

Fig. 36 illustrates places to apply solder on terminals.

When soldering terminal punchings and especially those of terminal blocks, care must be exercised to prevent the solder





from running to any place except the spot where it should be applied. On terminals extending horizontally or downward this is not difficult. On terminals extending upward it is almost certain that solder will run down the side of the terminal if too much solder is applied. This will usually result in trouble.

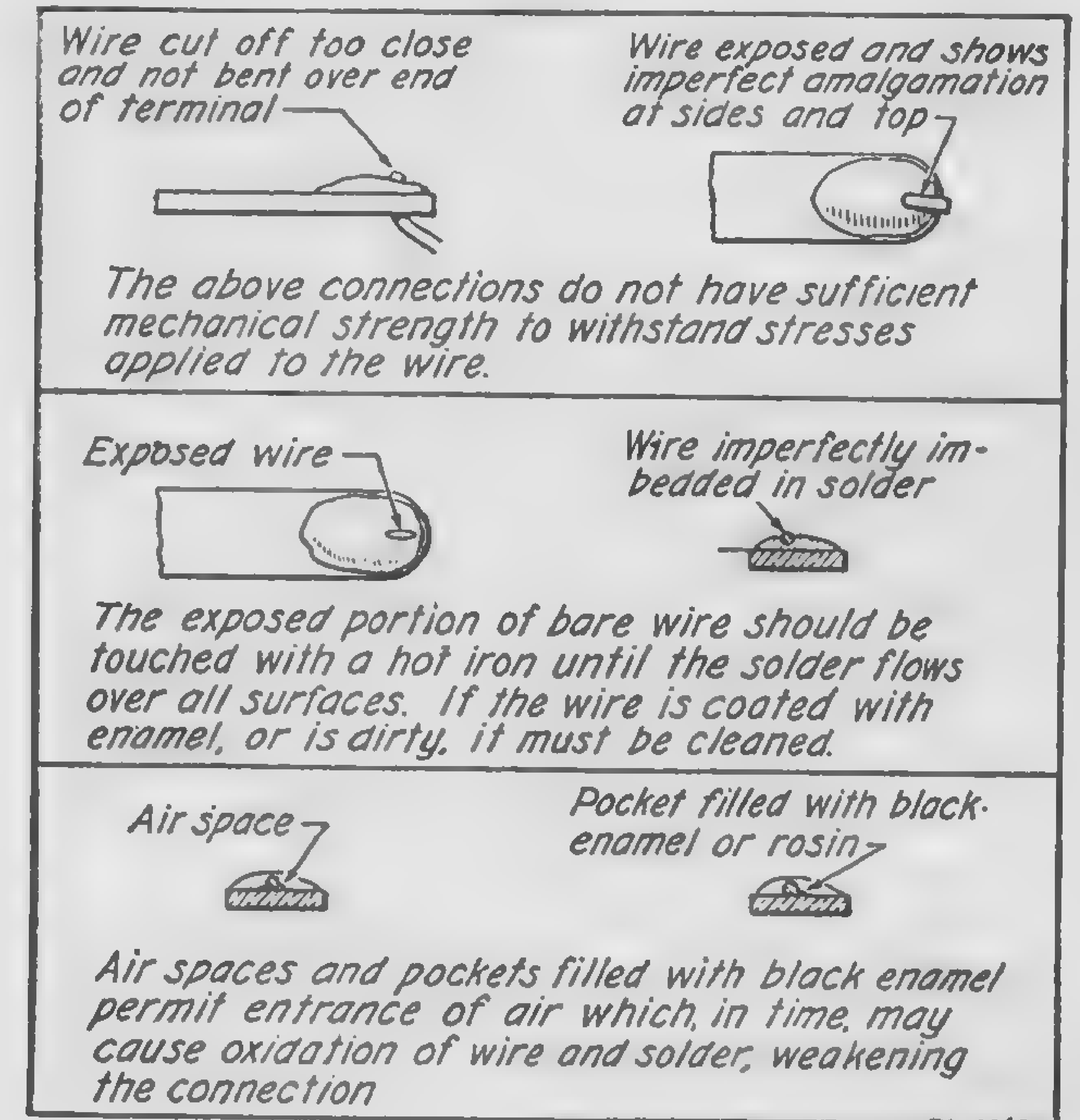



Fig. 35

The process of soldering small terminals of radio and telephone equipment by sweating, except for some special reason, is not practical or necessary. The greatest disadvantage to its use is that sweating is too slow; the second objection being that it requires more heat to sweat the joint. This added heat will sometimes cause the compound or fiber in which the terminals are set to melt and loosen the terminal.

The amount of solder usually required for small terminals can easily be obtained by laying the end of a piece of rosin core solder on the terminal so that the length of the solder lying against the terminal extends over the spot where the solder is required. Then place the tip of a properly tinned and heated

iron on the solder. As soon as the solder melts, the piece of solder held in the hand is moved away from the iron tip. As soon as the solder on the terminal is completely liquid and is adhering to the wire and terminal as it did to the iron tip, remove the iron by dragging it off toward the terminal end.

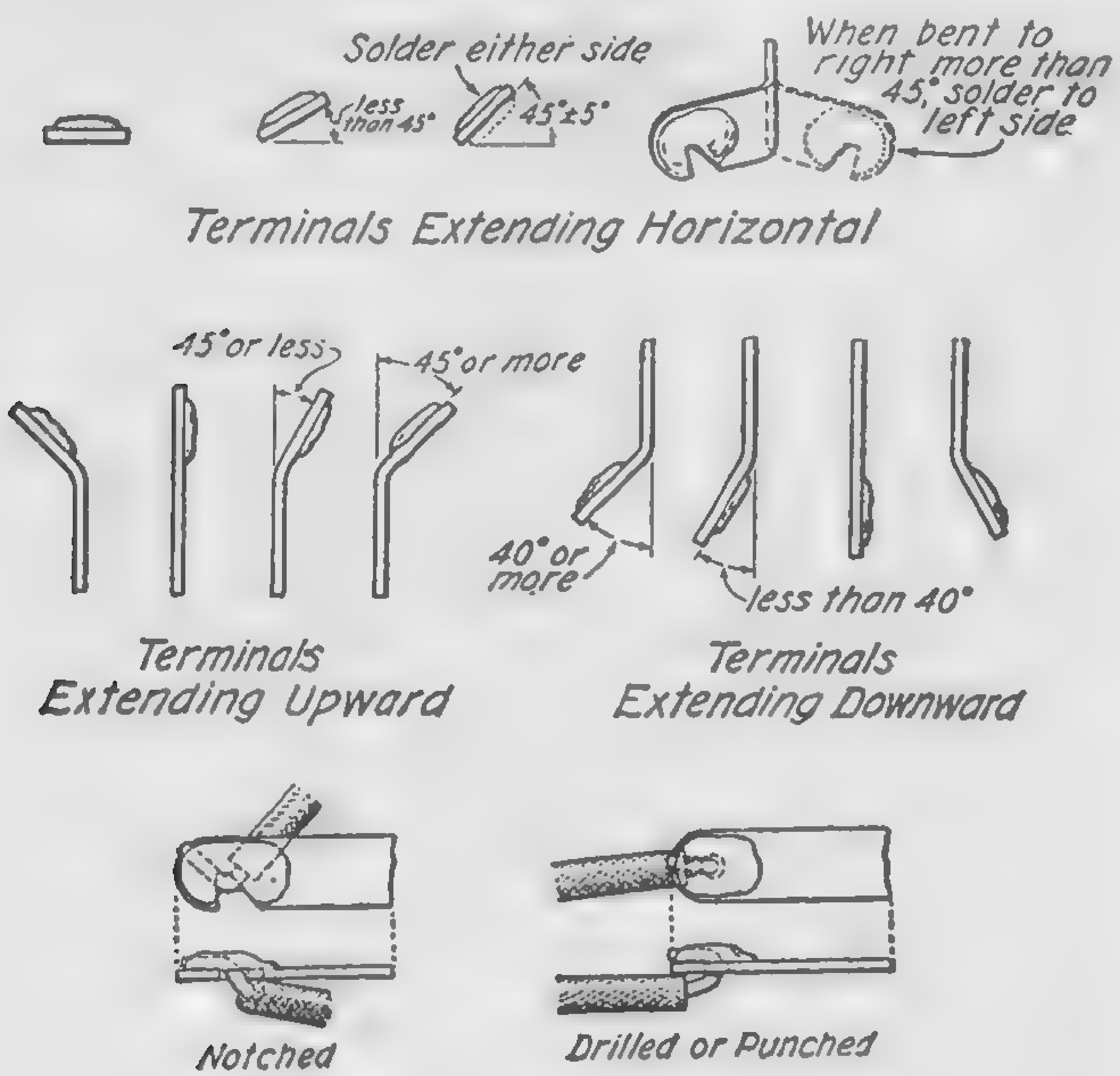



Fig. 36

Allow the soldered joint to cool before attempting to move wire or terminal. Excess solder may be removed by remelting it and flicking the excess off with a small wooden stick or toothpick.

All terminal blocks, relays, cable forms, or other equipment that is underneath terminals to be soldered, must be covered with canvas or cheesecloth before starting to skin or solder wires.

## WIRING OF RADIO EQUIPMENT, CORDS AND PLUGS

**Bus Wiring.** Bus wire for radio equipment is usually No. 14 B&S gage, or larger, tinned copper wire. This wire may be round or square. Heavy, enameled copper wire may also be used for bus wiring. The tin or enamel coating on the bus wire prevents corrosion and, in case of tinning, simplifies soldering.





Bus wire is used where a large current or a high-frequency current is to flow through the wire. Bus wire makes a very strong job mechanically; however, if there is any danger of it coming in contact with other wires in the set, it should have some sort of insulation placed over it.

There are two methods of joining one piece of bus wire to another: the butt joint and the loop joint. See Fig. 37.

In the butt joint, one end of the wire to be soldered to the other is bent to a right angle to form an "L." The bent-over part should be from one-fourth to three-eighths of an inch long. The bend must not be too sharp or the wire will be broken. Solder

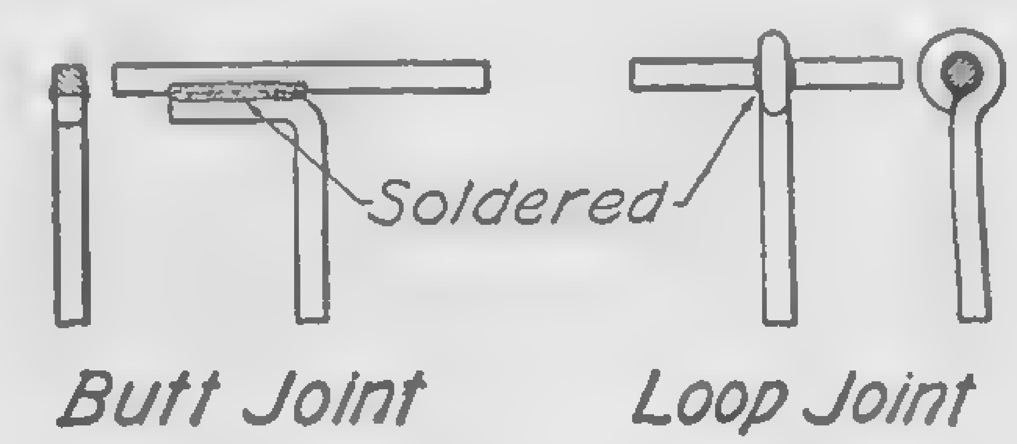



Fig. 37

is then run in between the wires, a small amount of solder is built up on the joint. This type of joint is usually used when wiring with square bus wire.

The loop joint is used when wiring with round bus wire, or with enameled wire. This joint is made by bending a small loop on the end of the wire to be fastened to another wire, then this loop is placed over the wire and clamped in place with a pair of pliers. The joint is then soldered. The solder *must* be run in the loop.

Comparison of the two connections shows the loop joint to be much stronger than the butt joint, as the loop joint has added strength because one wire is actually clamped around the other. The strength of the butt joint depends on the *solder only.*

When enameled wire is to be used, the enamel must be removed from the wire before soldering. A fine line should be scribed around the wire, then the enamel scraped off from that point to the end of the wire. This makes a neat job. When making a joint in the middle or part other than the ends, two lines are scribed and the enamel removed between these two lines.

**Loop Bending.** It is sometimes necessary to bend loops where a wire is to be fastened around a screw. This is best accomplished with the aid of a pair of long-nose pliers. The loop is made by holding the extreme end of the wire in the points of the pliers, the left thumb resting on the wire and partly on the points of the pliers. Make a slight bend on the end of the wire; the amount of this bend will depend on the size of the loops required. Move the pliers slightly back on the wire and make another bend, continue until the loop is completely formed. Place the pliers at (*a*), as in Fig. 38, shape the loop to look like the figure marked "completed loop."

A loop in stranded wire is made in the same manner; however, it is necessary to clean and twist the strands together, then tin the wire before a satisfactory loop can be completed.


Fig. 38

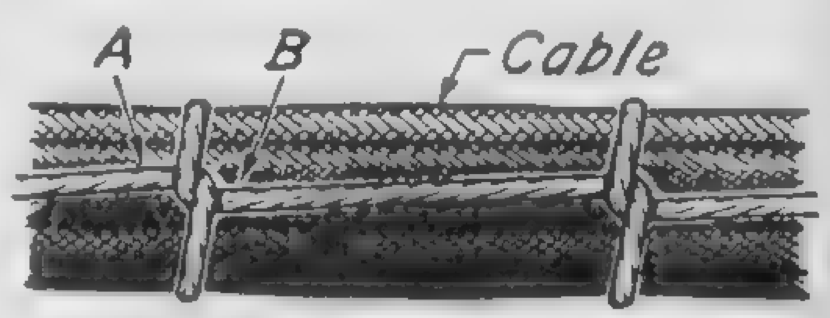



Fig. 39

**Cable Wiring.** Cable wiring is used where a number of wires follow the same path. The wires are laced into a form, either before or after being soldered to their respective terminals, depending on the type of work being done. The wires are laced together with the lock stitch, illustrated in Fig. 39. *Do not use a half-hitch* because it will not hold the form together if the lacing cord is broken.

Note the points on the diagram in Fig. 39 marked *A* and *B*. At these points the twine must be on the *under* side. If either *A* or *B* is on top when the stitch is made, it is called a *half-hitch* stitch. The half-hitch will loosen if the twine is broken.

A figure-eight knot is used to start the lacing. The short end of the cord should be carried under the first two stitches and then cut off. When the cable lacing is completed, the twine is anchored by placing two or three stitches behind the last stitch of the form. See Fig. 40.

Do not lace wires carrying *high voltage* or *high frequency* current in a cable with other wires.





A type of wire, called "pushback" is normally used to wire radio sets. It is simply a tinned copper wire with an insulation that can easily be pushed back from the end. This saves time and gives the installation a neat appearance.

Shielded wire is usually grounded to the frame of a set or, if used externally in vehicles, to the body of the vehicle. This is accomplished either by soldering a pigtail and lug to the shield or by unraveling the strands of the shielding, twisting them to form a wire, and soldering this to the nearest ground. If the ground is not near enough to the point of termination to use this method, solder a piece of stranded pushback wire to the shield and run it to the ground.

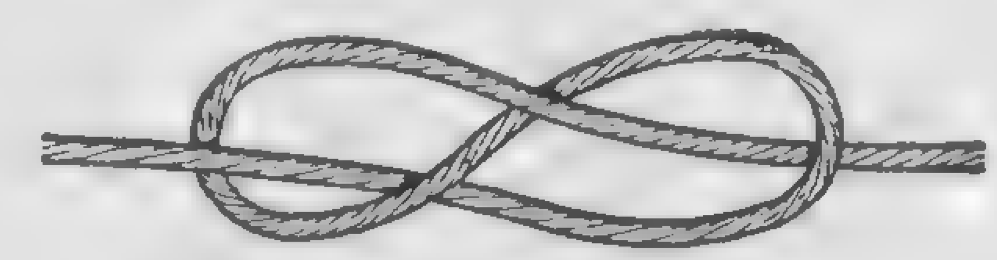


Fig. 40

## CORDS AND CORDAGE

**Definition.** Cordage is the bulk cable used in the fabrication of cords. *Cords* are pieces of cordage cut to the proper length, with the ends prepared for the application of plugs. They may be prepared with or without the proper plugs.

**Use.** There are many types of cords used in the installation of radio sets. Cords are used to interconnect the component parts of radio sets in aircraft, portable, and vehicular installations. The type of cord to be used is determined by the particular installation and is covered by instructions for the installation of each different type of equipment.

**Description.** Cordage in general has from 2 to 8 conductors, each conductor having an insulating cover of rubber. The conductors are twisted together, jute or cotton packing being added to give shape to the cord, and covered with an insulating tape which, in turn, usually is covered by the shield. The shield is composed of small tinned copper wires braided around the taped conductors. The shield is covered with a rubber jacket which insulates and protects the entire assembly. In some cases the shield is on the outside of the rubber jacket. This last type

of cordage is used extensively in aircraft and vehicular installations where bonding of the cords at frequent intervals is essential. The conductors in cordage are generally color coded, each conductor having a different color rubber insulation to facilitate the tracing and connecting of the conductors. When the conductors are not coded, an ohmmeter or some similar means must be used in tracing the conductors. Cords, in most cases, are fitted with plugs which fit into sockets on the equipment, thus making the necessary connections between the units. This is not true in all cases however. In some equipment the cords are connected to terminal strips in the units.

*Common Troubles.* One of the most common troubles to be found in cords is the breakage of conductors at or near the plugs or at points where the cord is bent too sharply, as in going around the corner of some piece of equipment. A cord should be long enough so that no strain is placed on it at any time. Another common trouble is twisting of the cord in the plug, thus shorting or breaking the conductors in the plug. Be sure the plug is properly clamped on the cord.

## PLUGS AND SOCKETS

**Use and Description.** Plugs are used on the ends of most cords to facilitate the connecting of the cords to the units. The plugs fit into sockets which are usually mounted in the various units of the equipment. There are so many different types of plugs and sockets that no attempt will be made to describe them in this lesson, as the student will become more familiar with the various types as he works with the equipment. Most plugs and sockets have the connecting pins so positioned that the plug can only be inserted into the socket in the correct position. Most plugs are also equipped with some locking device to prevent the plug from being pulled out of the socket accidentally. Plugs and sockets usually have the pins and connections numbered or marked in some manner so that they may be properly connected. The wiring diagram of the equipment shows these numbers or markings so that trouble shooting and repair of the equipment is simplified.





**Common Troubles.** One of the most common troubles found in plugs and sockets is a poor connection between the plug and socket. One type of socket commonly used has banana plugs for the socket pins. The springs on these pins become compressed and fail to make a good connection. This may be cured by spreading the springs with a small screw driver or a scriber. Plug shells frequently become so battered from dropping and other abuse that they do not fit the sockets properly. If not too badly damaged they may be reshaped and continue in service. The locking devices sometimes become damaged through accident or abuse. If not too badly damaged they should be repaired and used.

## REPAIR OF CORDS

The following information on the repair of cords is necessarily of a general nature. The instruction books covering the different types of equipment and the installation of the units usually cover the makeup of the associated cord. In all cases these instruction books should be consulted and instructions followed when repairing or making cords.

**Preparation of Cords.** Rubber jacketed cords will be considered in this lesson, since this is the most commonly used type. The first step is to cut the cordage to the proper length. If an old cord is being used or repaired, the conductors should be checked for continuity with an ohmmeter or by some similar means. Next, cut off the rubber jacket for about 1 inch, being very careful not to cut into the shield. Diagonal pliers are the proper tool to use in cutting off the jacket. Tin the shield for a space about ⅛-inch wide next to the rubber jacket. Refer to Fig. 41 at (*a*).

The next operation is to solder the ground lead to the shield, where the shield was tinned. Remove about 1½ inches of insulation from one end of a 6-inch piece of No. 18 stranded, rubber-covered wire. Wrap the bare end around the tinned portion of the shield and solder into place. Be sure it is well soldered. Next cut the shield off back to the tinned portion, at the same time removing the insulating tape and cutting out the cotton or jute packing cords. Be careful not to cut the insulation on

any of the conductors. Now the insulation may be removed from the ends of the conductors and the ends tinned. Do not remove too much insulation, an eighth of an inch being sufficient in most cases. The insulation on the conductors is usually live rubber and, unless extreme care is used, too much insulation may be pulled off. Do not use a knife to remove the insulation. Nip it loose with the points of the diagonal pliers. Twist the strands of each conductor together neatly and tin them as soon as the insulation

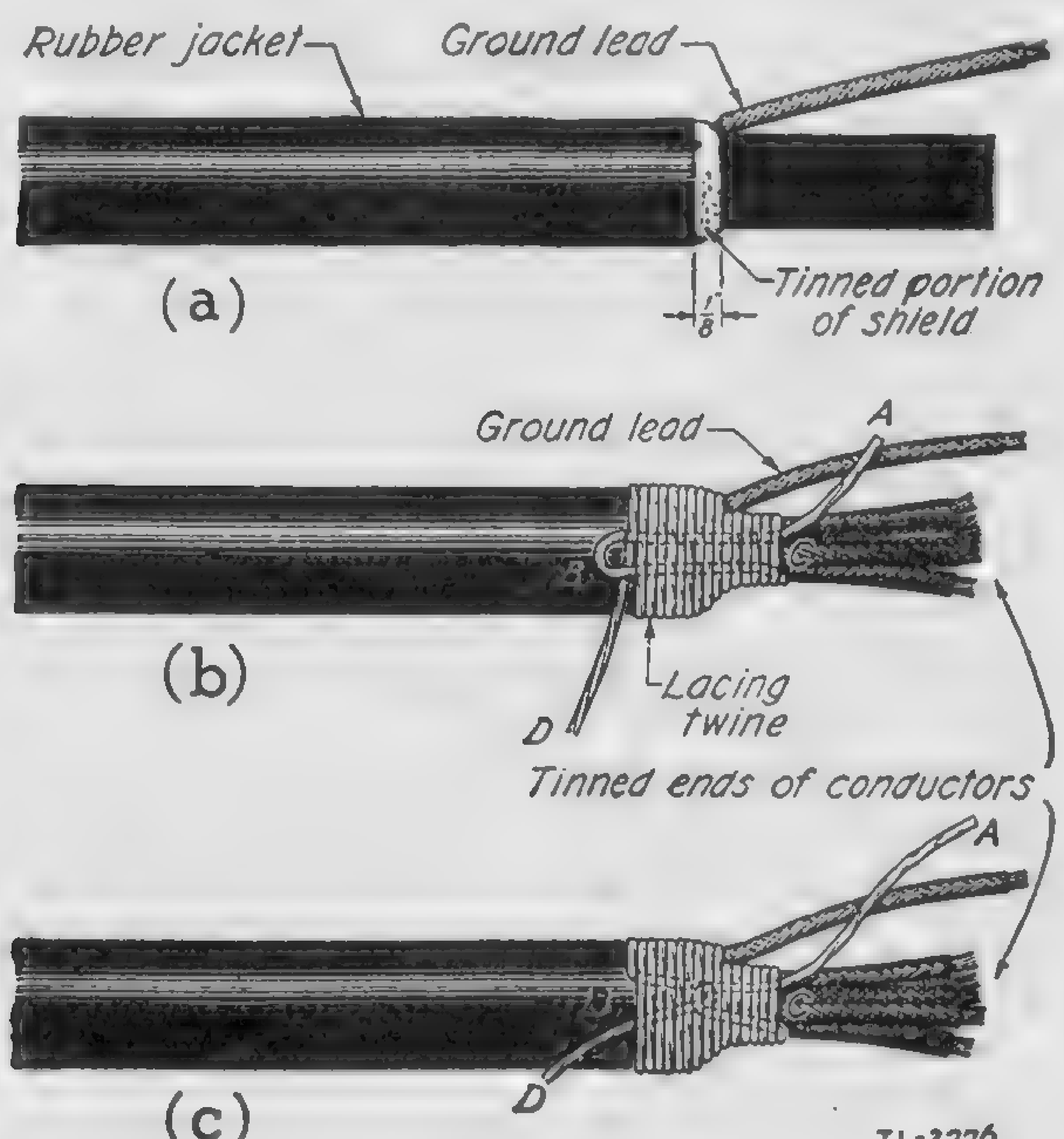



Fig. 41

is removed. As soon as this operation is finished, the end of the cord will be served with waxed lacing twine. The Signal Corps type number of the twine generally used for this purpose is *RP-13*. The following explanation and Fig. 41 at (*b*) and (*c*) will show how this serving is applied.

A piece of twine about 18 inches long is used. One end of the twine is laid along the cord in a loop as shown by *ABC* in Fig. 41 at (*c*). Leave end of twine *A* about 4 or 5 inches long and end of loop *B* about 1 inch back from the end of the jacket. Beginning at *C*, wrap 3 or 4 turns of twine around the conductors,





drawing the twine very tight. Do not include the ground lead when making these first 3 or 4 turns. Now include the ground lead and continue wrapping the twine until about 4 turns are made over the rubber jacket. Keep the twine pulled tight at all times and keep the turns as close together as possible. Make the serving look as neat as you can by working the turns into place with the fingers, as they are put on. Now put the end of the twine *D*, Fig. 41 at (*b*), through the loop *B*. Pull on end *A* pulling loop *B* under the wrapping as shown in Fig. 41 at (*c*). This draws the end *D* under the wrapping at the same time and thus ties the serving in place without the use of knots. Cut off the ends *A* and *D* close to the wrap and the job is finished.

**Preparation of Plugs.** The plugs should be inspected to see that they are of the proper type and are clean and free from corrosion. If old plugs are to be used, the old solder should be removed and the plugs thoroughly cleaned. When removing solder from the plugs having the pins or jacks permanently fastened into a bakelite block, care should be exercised not to use too much heat as this causes the Bakelite to swell and the shell will no longer fit over it. Too much heat also causes the Bakelite to break down, and results in electrical leakage between the pins. See that all screws are in place and have lock washers on them, and that the locking device is not damaged.

**Soldering.** When soldering the conductors into the plug do not hold the soldering iron on the connection too long. As stated previously, this will cause trouble during and after assembly. Be sure that the necessary plug parts are threaded on the cord, before soldering the plug in place. Check your wiring diagram and color code thoroughly before starting to solder the conductors. Double check all connections while soldering. If there is any doubt as to the colors of any of the conductors, use an ohmmeter or some similar means to check them through. Do not use too much flux or solder. Surplus flux and solder should be cleaned from the connections and plugs. Be sure that all strands of the conductors are soldered into place. Free strands may cause short circuits or grounds. See that the insulation is not damaged on the conductors. If necessary, insulating tape or cloth should be used to insulate the conductors.

**Assembly of Cords and Plugs.** When all connections have been soldered and inspected, the plugs may be reassembled. When fitting the plug parts together, be sure that the conductors are not pulled tight or twisted together any more than is absolutely necessary. See that all the screws used in the assembly have lock washers on them. Be sure that the locking device is free and operates properly. See that the cord is properly clamped in the plug. If necessary, a layer of rubber tape should be used under the cord clamp.

**Testing of Cords.** After assembly it is advisable to check the cord with an ohmmeter, or by some similar means, to see that the conductors connect through the proper pins at each plug. The most satisfactory method of testing the cord is by installing it in the proper equipment and trying it under actual service conditions. Quite often a cord, when put in service, will develop trouble that does not show when tested by other means.





PART 4

# Woodworking

Following is a descriptive list of the more essential tools used in woodworking, together with instructions in their use.

## HAND CUTTING TOOLS

**Rip Saw.** Hand saws are of two kinds—rip, and crosscut. The former, as the name indicates, is for cutting with the grain, or lengthwise of the board to be sawed. In Fig. 8 is illustrated a rip saw having 5½ points to the inch, which will work rapidly and with ease in pine and other soft woods. If mahogany, cherry, or other hard wood is to be ripped a 6-point saw should be used.

*Hook of Teeth.* Rip saws should be filed with all the bevel on the back of the tooth, as shown at *b* in Fig. 8, the front or throat of the tooth being at right angles to, or square with, the tooth edge of the blade, as at *a*. The position of the line *c d*, whether perpendicular or slanting, is called the *hook* or pitch of the tooth.

*Filing and Setting.* Rip saws should be filed square across; that is, the file should be kept horizontal and at right angles to the side of the blade, always filing each alternate tooth from the opposite side of the saw; this, if done by beginning at the heel and working the file toward the point of the saw blade, gives a very slight bevel to the back edge of the tooth, causing it to cut cleaner and to require less set than if filed otherwise.

Rip saws require very little set for use in dry, well-seasoned lumber, such as is ordinarily used in woodworking. The teeth should be set, or bent, only at the points, as shown at *e* and *f* in Fig. 8—in no case should the set exceed more than half the depth of the tooth. When only the points are set, the saw works more freely, and the blade of the saw is not sprung or bent in setting.

In using a rip saw, the front or cutting edge of the saw blade

should be held at an angle of about 45 degrees to the board, as shown in Fig. 9. This brings the back of the tooth nearly at right angles to the fibers of the wood, and insures a shearing cut. For fine work and well-seasoned material, hand saws may be bought ground so thin on the back as to require no set. Such tools work very smoothly and easily, cutting away less wood and doing better work than saws that have been set.

**Crosscut Saw.** The crosscut saw really severs or cuts the fibers of the wood twice, as shown at *a* in Fig. 10, the intervening pro-

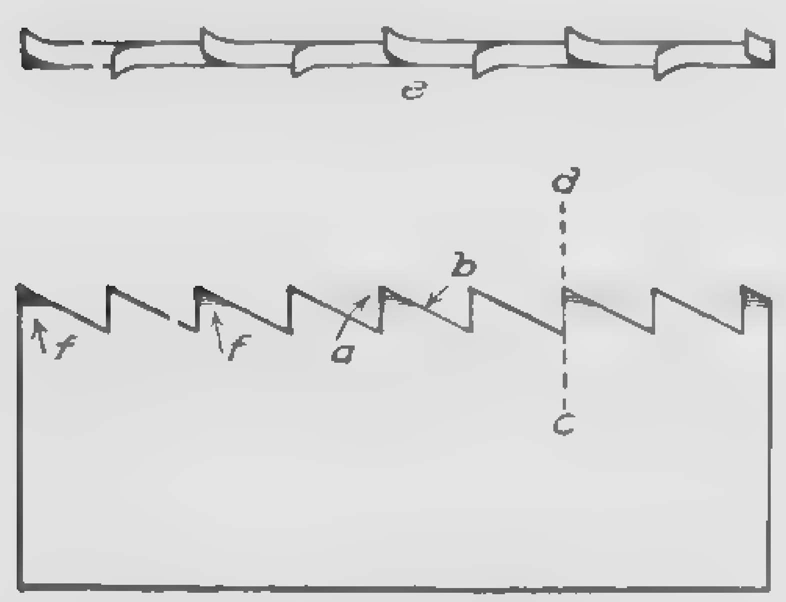



Fig. 8. Teeth of Rip Saw

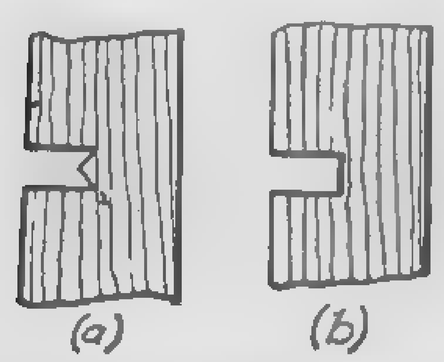



Fig. 10. Kerf Made by Crosscut Saw

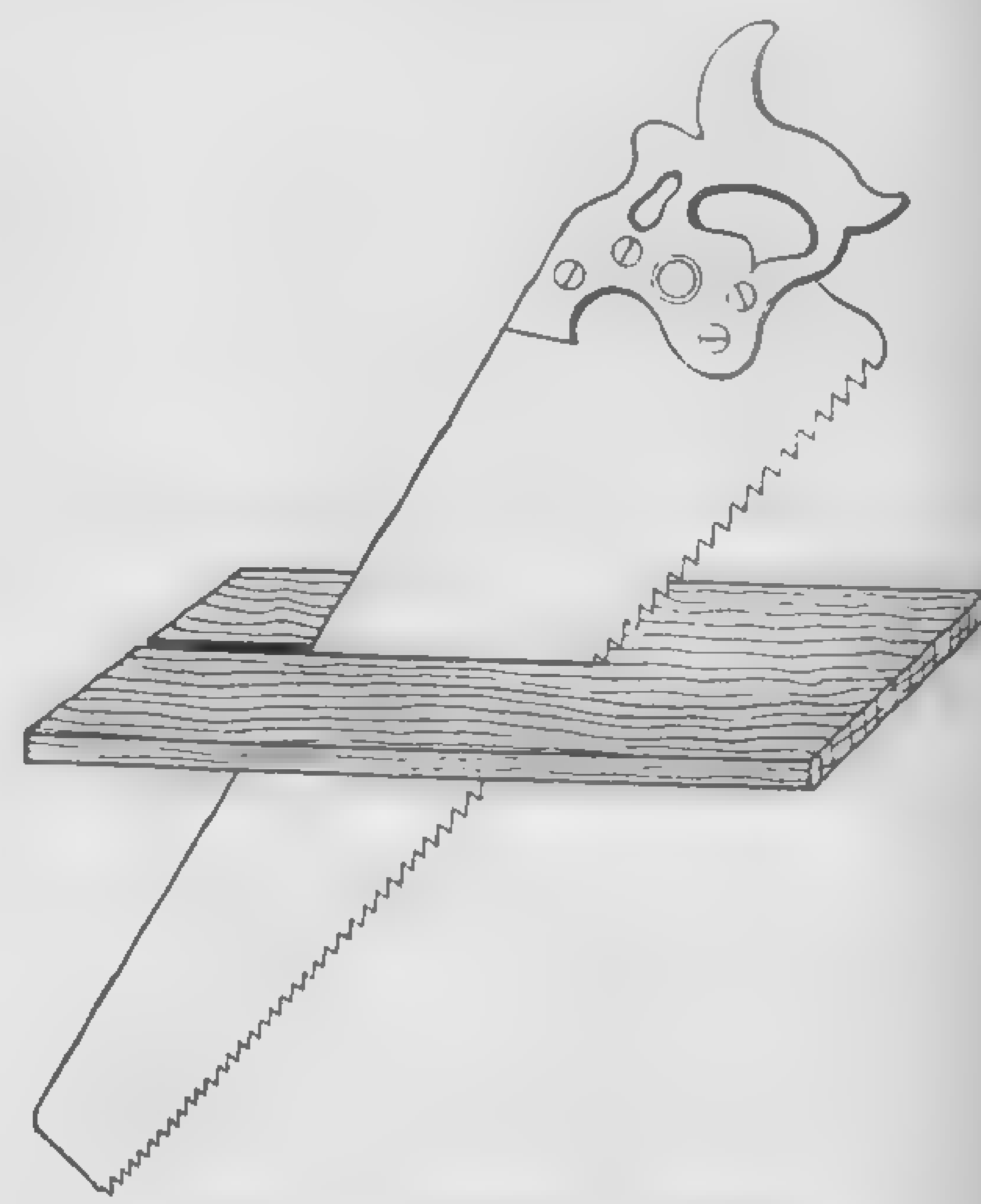


Fig. 9. Position in Ripping

jections being loosened and carried out as dust by the thrust of the saw, producing a nearly straight-bottomed kerf, as shown at *b*.

A crosscut saw for ordinary work should have 5 or 6 points to the inch; but for fine work 10 or 12 points would be better, especially for dry woods, either soft or hard. A section of a 6-point crosscut saw is shown in Fig. 11, and one of a $13\frac{1}{2}$-point in Fig. 12.

*Shape of Teeth.* We find that while the rake or tooth bevel in rip saws is all on the back of the tooth, the rake in crosscut saws is on the side of the tooth, as shown at *a*, Fig. 11. In ripping, the point of the tooth acts as a chisel, cutting off the fibers of the wood, each tooth chiseling off a shaving as it passes through the board; but in crosscutting, the side of the tooth does the cutting, and therefore must have its bevel on the side.





In Fig. 11 the *fleam*—angle of the tooth with the plane of the saw blade—is about 45 degrees, and, as shown, there is no hook or pitch, the vertical angles being the same both front and back of the tooth. This form of tooth works well in wet or in very soft wood; but for wood that is well seasoned, and for all the harder woods, the pitch, or vertical angle or inclination, of the front of

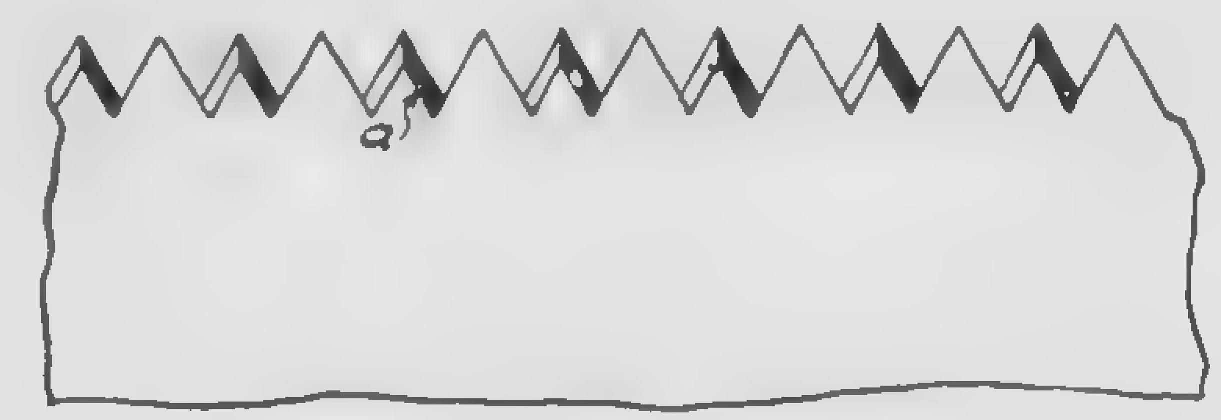



Fig. 11. Crosscut Saw Teeth

the tooth should be about 60 degrees to the tooth edge of the blade, as shown at *b*, Fig. 13. The amount of pitch in the teeth of a saw may be varied for different purposes or for different woods, but should be such as to loosen and carry out the intervening wood. Otherwise this would have to be rasped or filed out by the continued action of the saw.

*Filing.* The fleam or horizontal angle of the side of the crosscut saw tooth is very important. When filing, the file should be

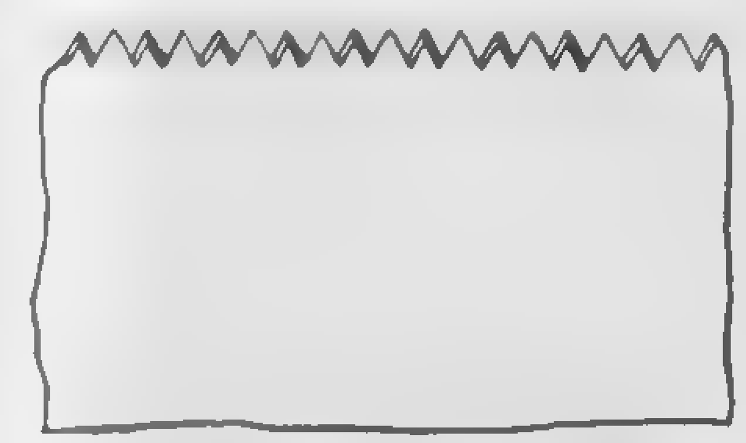


Fig. 12. Crosscut Teeth for Fine Work

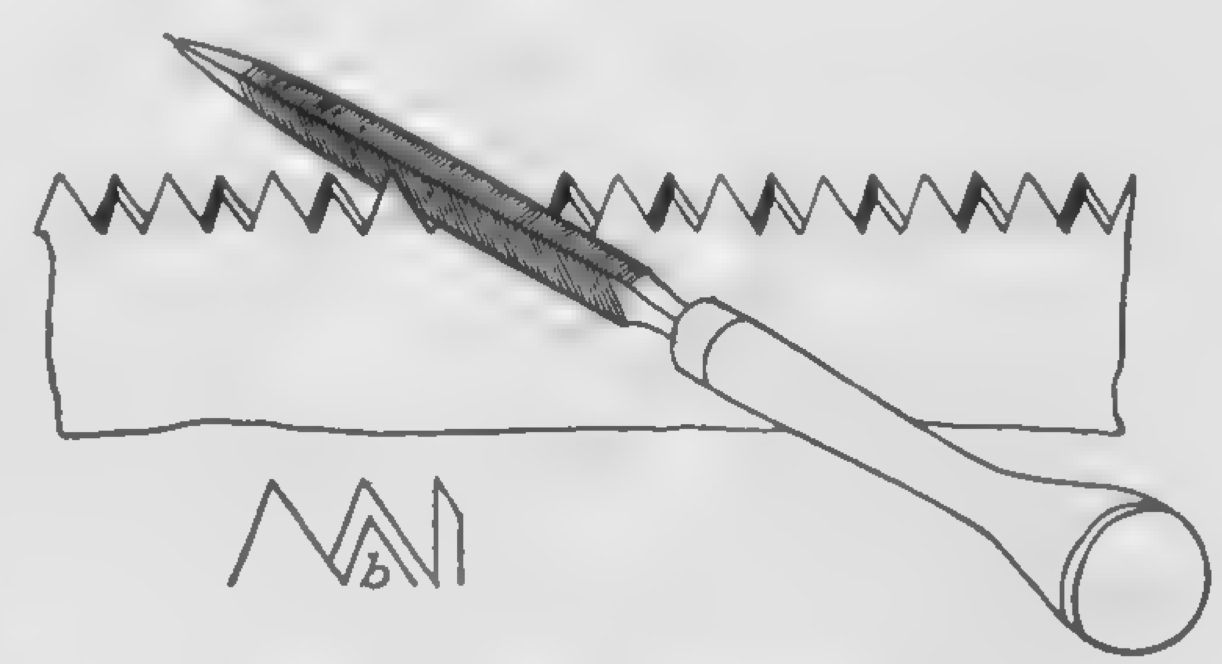



Fig. 13. Filing Crosscut Teeth

held horizontally and at an angle of about 45 degrees to the side of the saw, lengthwise of the blade, as illustrated in Fig. 13, and each alternate tooth must be filed from the opposite side of the blade, beginning at the heel and filing toward the point of the saw.

The objection is often raised by saw filers, that, in filing from the handle end of the saw toward the point, a featheredge is made

by the file and turned backward on the point of the tooth. The first thrust of the saw through the board, however, will remove this featheredge entirely; whereas, if the filing is done from the point of the saw toward the handle, it is necessary to file the teeth bent toward the operator, which causes the saw to vibrate, or chatter, and this not only renders good even filing impossible, but breaks the teeth of the file.

*Setting.* In the saw factory, hand saws are commonly set by striking a light blow with a hammer on each alternate tooth while the teeth of the saw project just over the edge of a bevel on an anvil. A skilled workman can gage the strength of the blows to take care of variations in the spring of the steel and get a very uniform set. Skill to use this method is not usually found among users of saws so that some kind of an adjustable set similar to that shown in Fig. 14 is most common. These are of different styles but all operate in a similar manner. The movable handle of the tool clamps the saw firmly against an adjustable anvil and then operates a plunger which gives the point of the tooth the required set. The adjustment on the anvil is graduated so that the amount of set can be duplicated.

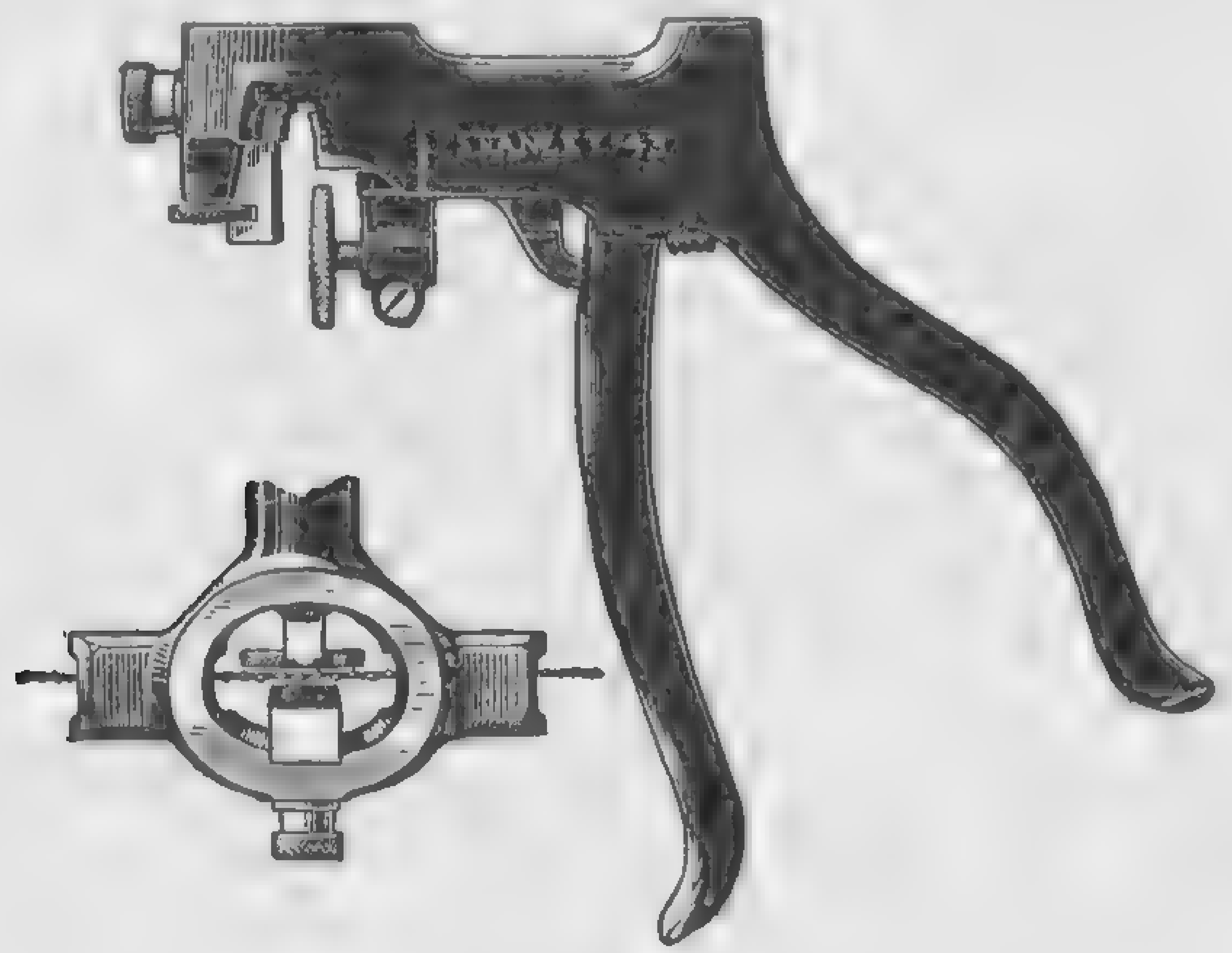


Fig. 14. Saw Set
*Courtesy of The Stanley Works, New Britain, Connecticut*

**Back Saw.** The back saw illustrated in Fig. 15 is used as a bench saw for light or fine work, and for fitting and dovetailing. Saws of this type are made from 8 to 14 inches in length, the 10- and





12-inch being convenient sizes for general work. As the metal back holds and stiffens the saw, a thin blade should always be selected. The methods of filing, jointing, and setting are the same as those described for the other hand saws. At least two back saws will be found necessary, one filed for crosscutting, and the other filed as a rip saw for cutting with the grain of the wood, as in the cutting of tenons and dovetails.

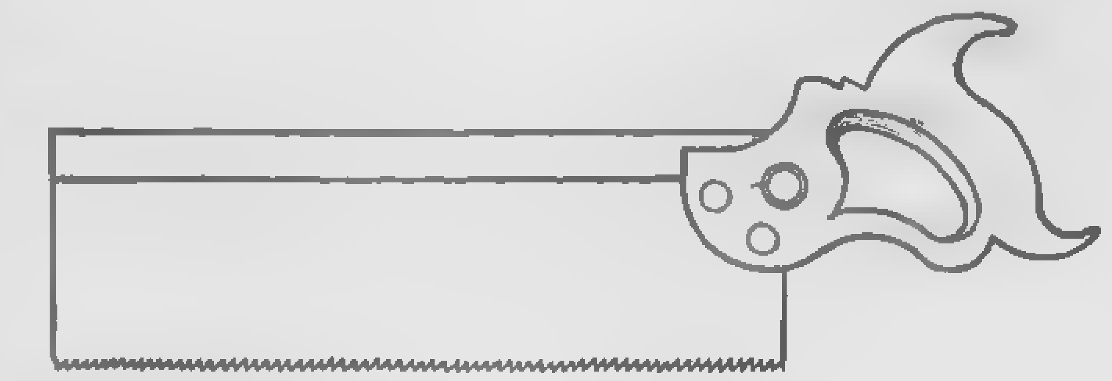


Fig. 15. Back Saw

*Exercise.* While for those who have had experience in carpentry the following exercise in the use of the back saw may not be necessary, it is recommended to all beginners who wish to acquire skill in the use of this important tool.

Take any block of wood from 12 inches to 16 inches long, about 2 inches wide, and about $1\frac{3}{4}$ inches in thickness. With try-square and a sharp-pointed pocketknife, lay it out, as illustrated in Fig. 16, on the upper, front, and back sides of the block. The knife cuts must be at least $\frac{1}{32}$ inch deep, and about $\frac{1}{4}$ inch distant from each other. Next proceed to saw up the block into thin sections, sawing each time so that the saw kerf will be just outside of, but close to the knife line, as indicated at *a*.

The saw cut through the block should be true to each of the three lines; and while the saw passes along one side of the line, its teeth should not scratch the opposite side of the knife cut, but should leave a smooth clean angle of the knife cut on the block, as shown at *b* in Fig. 16, while at the same time it should be so close to the line as to leave no wood to be smoothed off with plane or chisel.

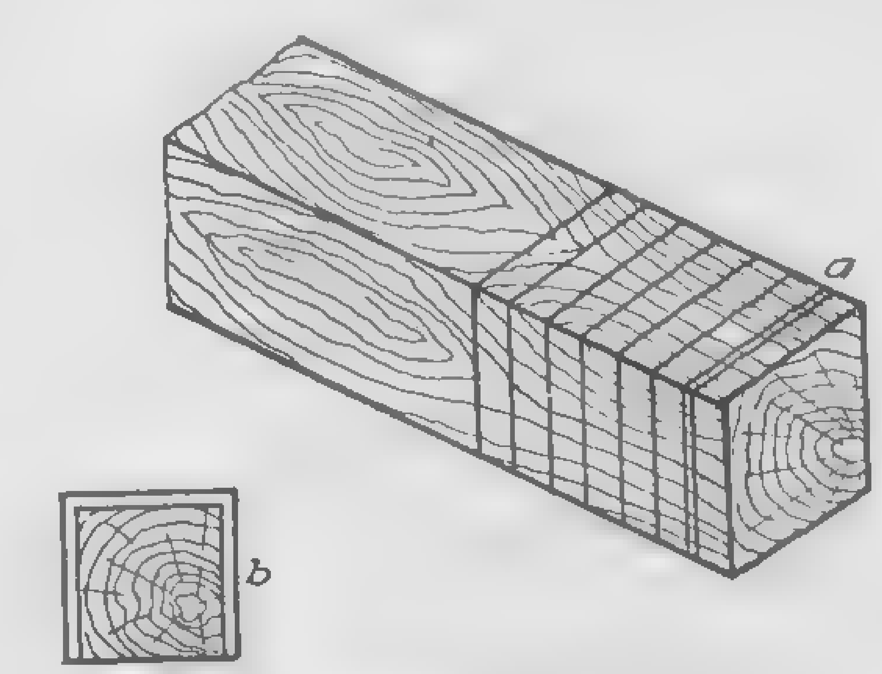



Fig. 16. Example of Back Sawing

A few hours' thorough and careful practice of this exercise will enable any one to use the saw successfully.

**Compass Saw.** As the work of the compass saw, Fig. 17, is both with and across the grain of the wood, the best form of tooth is that shown in Fig. 18, having more pitch, and slightly less bevel, than the crosscut saw. A crosscut saw will rip better than a rip saw will crosscut; hence the shape of tooth should be between the two. Compass saws are

ground very thin on the back of the blade, but in order to turn easily they should be set the same as hand saws.

And here we wish to impress on the beginner the necessity of keeping his saw—and, indeed, all other cutting tools—perfectly

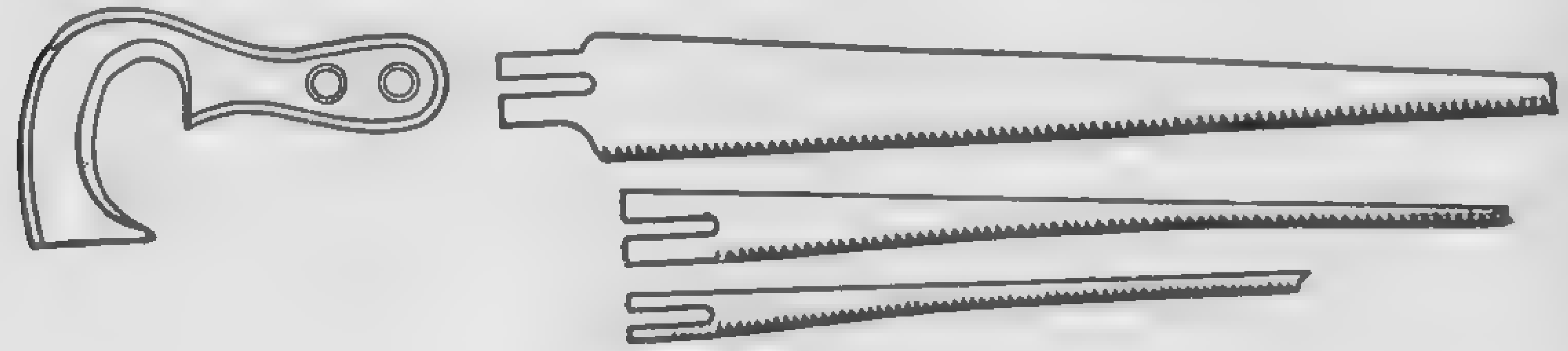


Fig. 17. Compass Saw

sharp and in good working condition at all times. A sharp saw works faster, and always does smoother and better work with less set and with less expenditure of power, than a dull one. Even to saw well is an art, which cannot be gained through the use of dull, imperfectly set, and poorly kept tools. To file well will require from the beginner close attention, a study of the subject, and careful practice, all of which can be given by any one possessing ordinary mechanical ability. If the filing is done slowly at first, care being taken to hold the file at the same angle for all the teeth, a little faithful practice will always bring success.

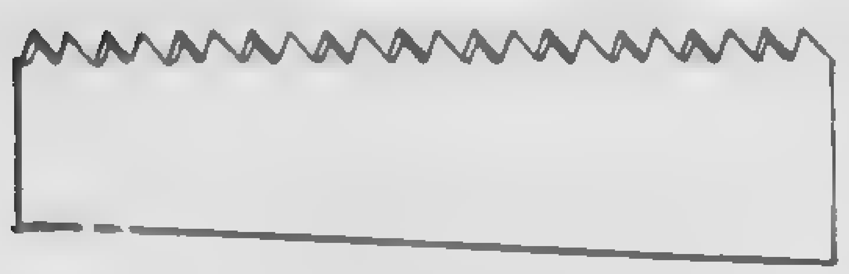


Fig. 18. Compass Saw Teeth

**Iron Plane.** The modern iron plane, illustrated in Fig. 19, can now be bought in a great variety of sizes and styles. These planes, with their true and unchanging faces, and their simple appliances for setting and adjusting the cutter, or plane iron, to the face of the plane and to the required thickness of shavings, are greatly to be preferred to the old-style wooden planes.

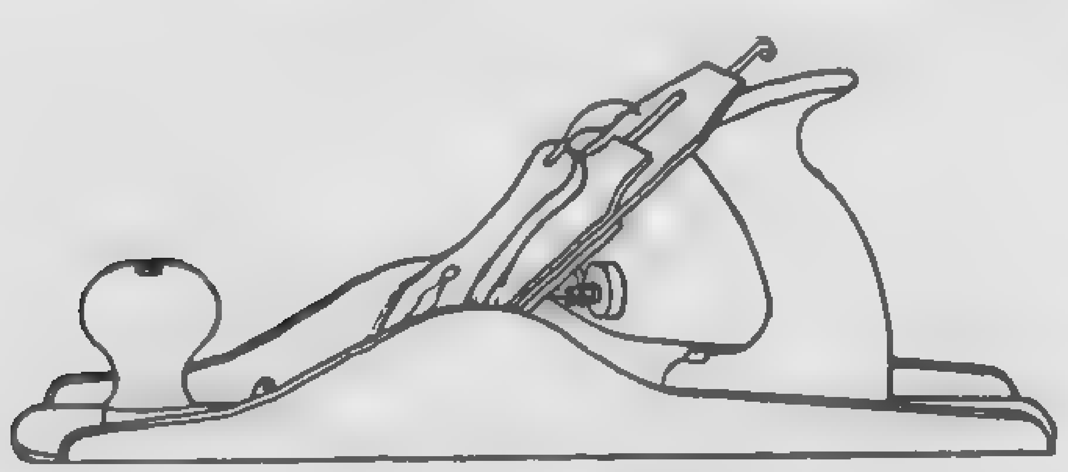


Fig. 19. Iron Plane

*Construction.* The general construction of the iron plane will be readily understood from Fig. 20, one side of the plane being removed to show the arrangement of the parts. The cutter, or plane iron *a* is made of the best cast steel, and is of equal thickness through-





out; in all new planes this part will be found ground and sharpened for immediate use. The cap iron *f*, Fig. 20, is fastened to the plane iron by an adjusting screw, as shown in Fig. 21. For whetting or grinding the cutting edge, it is not necessary to remove the cap iron, but only to loosen the connecting screw and to slide the cap back to the extreme end of the slot in the plane iron, tightening it there by a turn of the screw. The cap iron will then serve as a convenient handle or rest for the workman in whetting or grinding the blade.

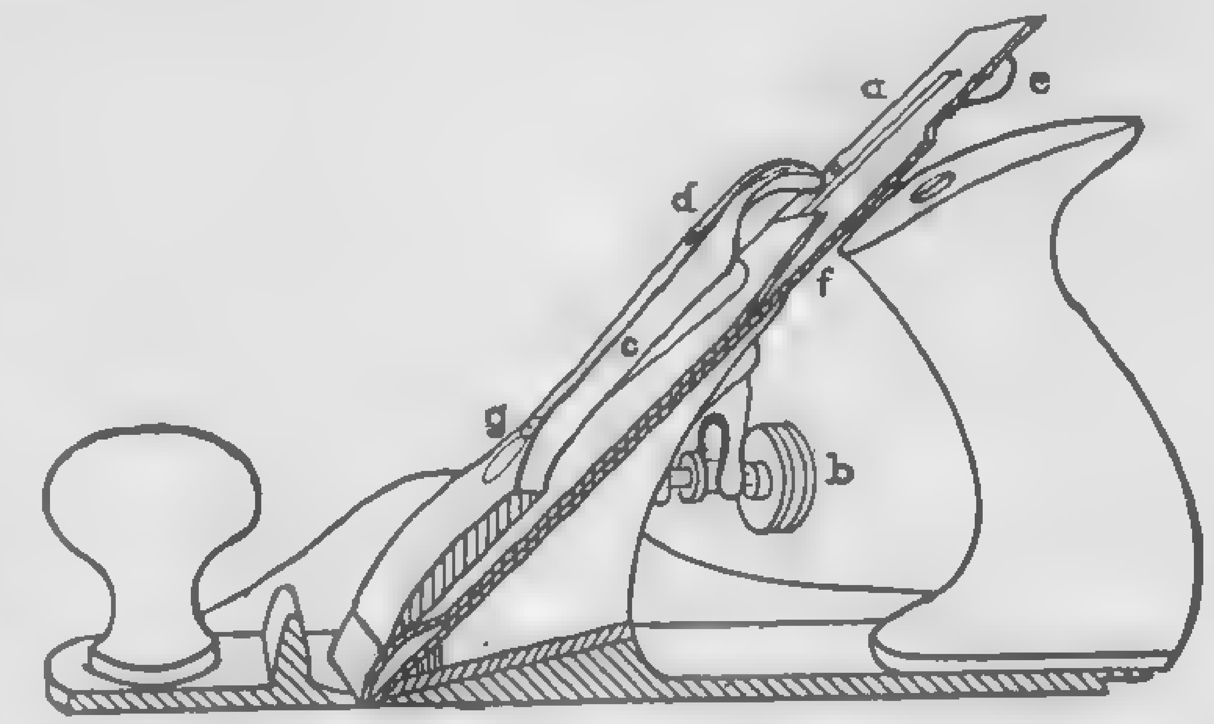



Fig. 20. Section of Plane

The iron lever *c*, Fig. 20, is held in place below its center by the screw *g*, which acts as a fulcrum, and the lever is readily clamped down upon the irons by the use of the cam piece *d*. When this cam is turned upward it ceases to bear upon the irons, and the lever *c* may then be removed from its place, and the irons released, without turning or changing the adjustment of the screw *g*, as the lever and irons are properly slotted for this purpose. Should the pressure required for the best working of the plane iron need changing, it can easily be obtained by tightening or loosening the screw *g*.

When the plane iron is secured in its place, the use of the brass thumb screw *b* will draw or drive the plane iron, and thus the thick-

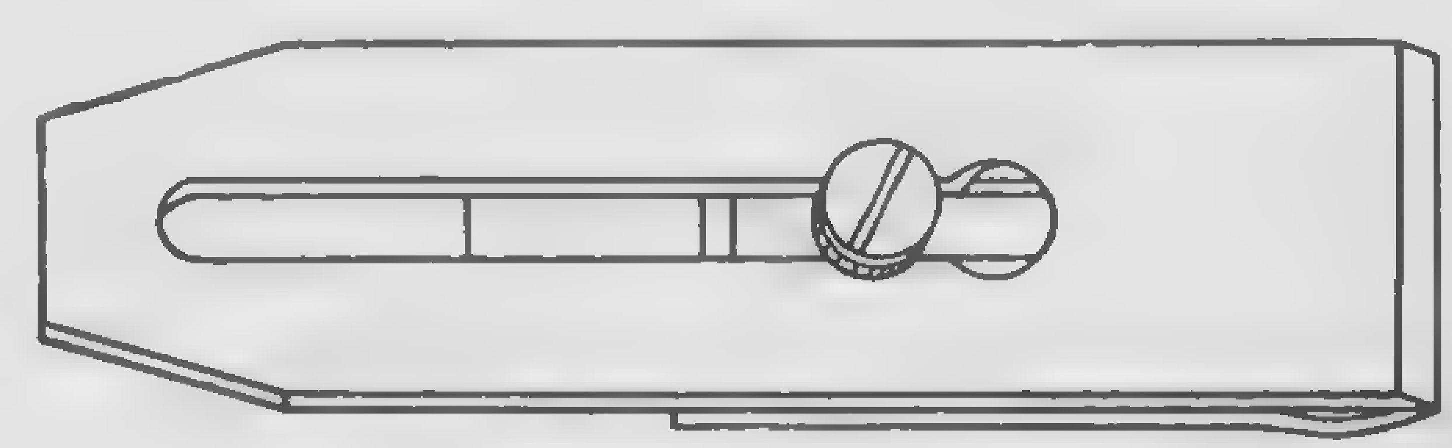


Fig. 21. Plane Iron—Cap Iron Connection

ness of the shaving to be taken from the work can be regulated with perfect accuracy. By the use of the lever *e*, located under the plane iron and working sidewise, the cutting edge can easily be brought

into position exactly parallel with the face of the plane, should any variation exist when the iron is clamped down. To ascertain this, hold the plane up, and look down over its face; the greater projection, if there is any, of one or the other of the corners of the iron, can readily be seen.

The cap iron *f*, which is not sharp, is not used for the purpose of strengthening or stiffening the cutting iron, as is often supposed, but as a chip break to prevent the cutting edge of the plane iron from chipping, tearing, and breaking the grain of the wood below the surface when the grain turns and twists, or when it is knotty and crooked. In such cases the tendency of the plane iron is to split and tear out the fibers of the wood in front of the cutting edge. To avoid this, the cap iron is screwed on, with its dull edge quite close to the cutting edge, so as to bend and break off the fibers or the shavings before the split gets fairly started below the surface.

The cutting edge of the plane iron is said to have lead in proportion to the distance it is placed in advance of the dull edge of the cap iron. The depth of the splits, or the roughness of the cross-grained surface, will be just equal to the lead of the cutting edge. For soft straight-grained wood the lead may be $\frac{1}{32}$ inch or even more, but this must be reduced in proportion as the wood is curly, cross-grained, or knotty.

*Grinding.* The grinding, or the whetting, must always be done on the bevel side only of the plane iron, the upper side being kept as flat and as smooth as possible to secure easy working.

All plane irons should be ground slightly rounding to the extent of the thickness of a thin shaving. This rounding of the cutting edge should be the true arc of a circle throughout the entire length of the cutting edge, and not simply a rounding-off of the corners as is sometimes directed. Rounding the edge to the extent of the thickness of a shaving prevents the plane iron from grooving into, or plowing out a wide groove in the surface that is being worked, and also assists greatly in working the edges of the piece to right angles, or square with the face side. To do this, it is not necessary, should one corner of the edge be higher than the other, to tilt the plane on the high edge, but, while holding it flat and firm on the surface of the edge being planed, the plane should be pushed side-





wise toward the highest corner in order to reduce that corner. This is readily understood when we remember that the cutting edge of the iron is rounding. If the plane is held so that the middle of the plane iron does the cutting, the shaving planed is of the same thickness on both edges; but if the plane is pushed over to one side, either to the right or to the left, the shaving will be featheredged, or thick on one edge and thin on the other, thus reducing the higher corner of the edge of the piece.

*Proper Use.* When the plane is to be used, the beginner should first carefully adjust it to the thickness of shaving required by moving the adjusting screw in the proper direction, at the same time holding it up and looking down over the face of the plane, when the projection of the plane iron can readily be seen. The cut should also be tested by trying it on the piece to be planed until the plane is ready for use.

The operator's position should be one of perfect ease, standing well back of the piece to be planed, and pushing the plane to arm's length from, not alongside of, the operator, taking long and continued shavings from the board. When starting the shaving at the end of the board, care should be taken to hold the forward end of the plane down firmly, or the act of pushing it forward will cause that end to tilt up and the plane iron to chatter on the surface as it begins to cut the shaving. This is due to the fact that nearly two-thirds of the plane overhangs the end of the board, requiring firm pressure on the forward end to balance it while the stroke is being started.

To insure smooth work, care must be taken to plane with the grain of the wood, and not against the ends of the fibers as they lie in the surface of the board. Should the fibers tear out and the surface become rough, reverse the ends of the boards so as to cut the shaving in the opposite direction, and note the difference in the effect on the planed surface.

**Common Types of Planes.** *Jack Plane.* Of iron planes, the most important is the No. 5 jack plane, 14 inches long, and having a cutter 2 inches in width, as illustrated in Fig. 22. When the lumber has first been roughly planed in a planing mill, this No. 5 plane can be used by the woodworker for the purpose of removing roller marks.

*Jointer Plane.* In making or in truing up very large surfaces, or in making long glue joints, the No. 7 jointer plane, 22 inches long and having a cutter $2\frac{3}{8}$ inches wide, will be found necessary. This plane is shown in Fig. 19, and differs from the jack plane only in its length and in its extra width of face.

*Smooth Plane.* For mahogany or other hard wood, the No. 4 smooth plane, illustrated in Fig. 23, will be found very useful. This

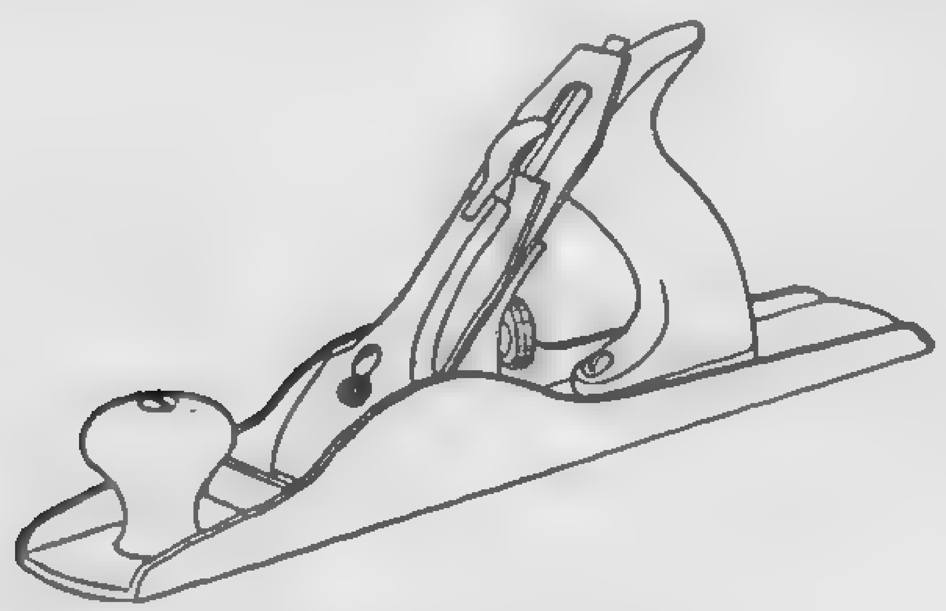


Fig. 22. Jack Plane

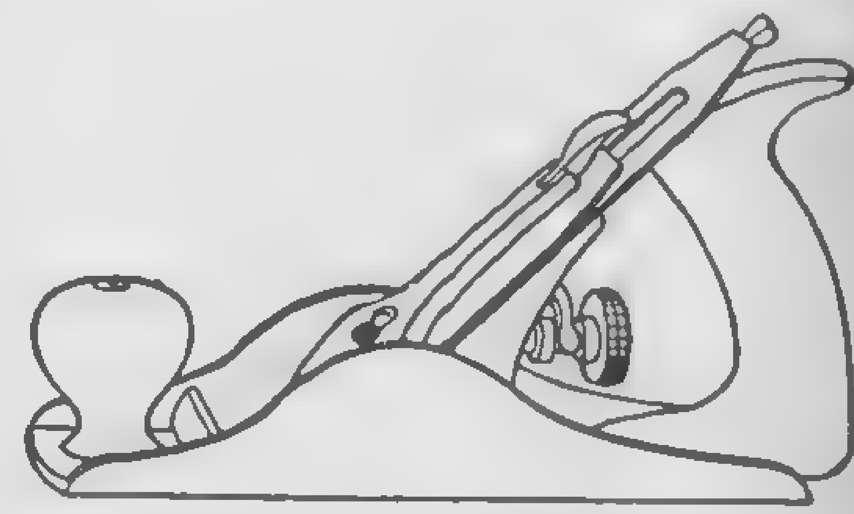


Fig. 23. Smooth Plane

plane is made in several sizes. The No. 4, which is 9 inches long and has a 2-inch cutter, is the best size for general use, particularly for smooth surfaces.

*Block Plane.* Next in importance to the three planes already mentioned, is the block plane, illustrated in Fig. 24. The No. 19, which is 7 inches long and has a cutter $1\frac{5}{8}$ inches wide, is the most desirable for use in end grain planing. It has an adjustable throat, as well as the screw and lateral lever adjustments of the other planes.

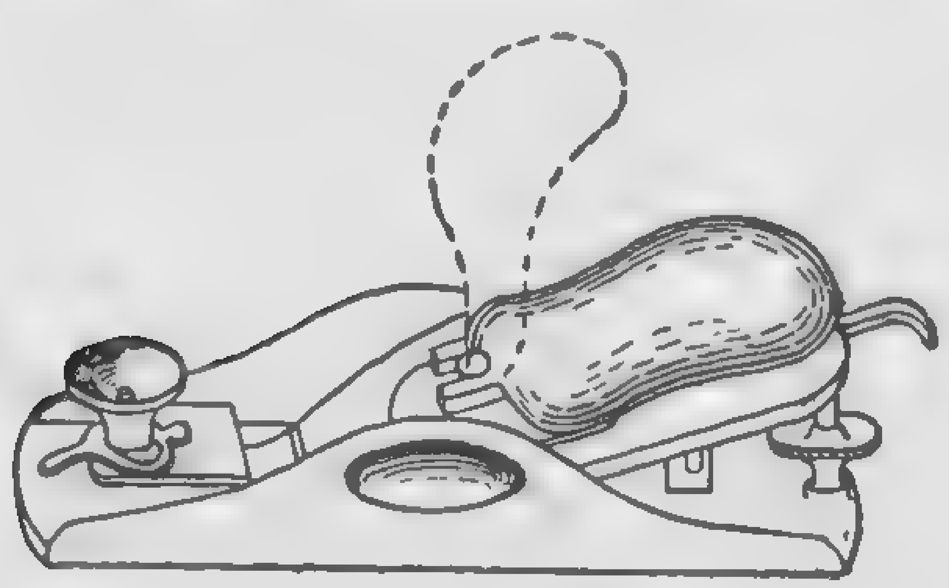


Fig. 24. Block Plane

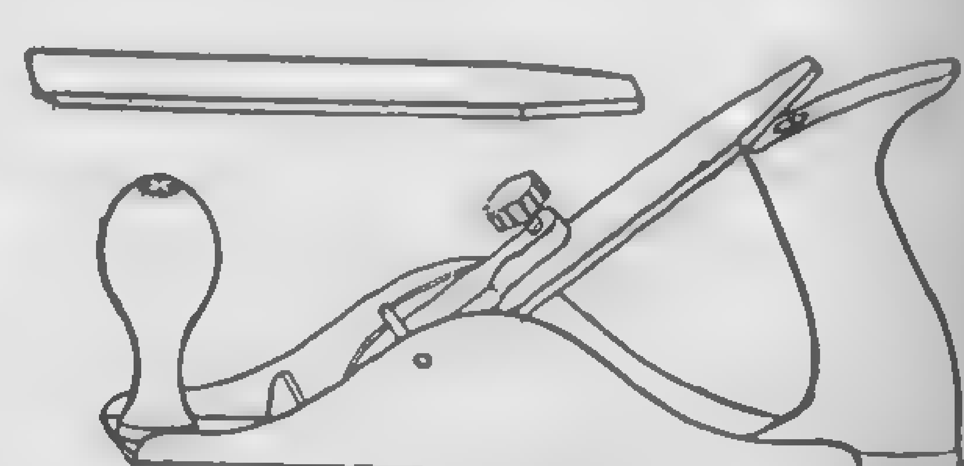


Fig. 25. Scrub Plane

This plane has the advantage of being so constructed as to be held easily in one hand, a fact which makes it especially adaptable for short work. Owing to the low angle at which the cutter is placed, it works more smoothly and easily on end wood and on miters than any other plane.





*Scrub Plane.* In cases where lumber must be dressed from the rough, without being first roughly dressed in a planing mill, the No. 40 scrub plane, illustrated in Fig. 25, will be almost indispensable. It is $9\frac{1}{2}$ inches long, and has a cutter $1\frac{1}{8}$ inches wide. The cutter is a single iron, and is ground and sharpened very rounding on the cutting edge, as shown in Fig. 25, to allow of cutting a very

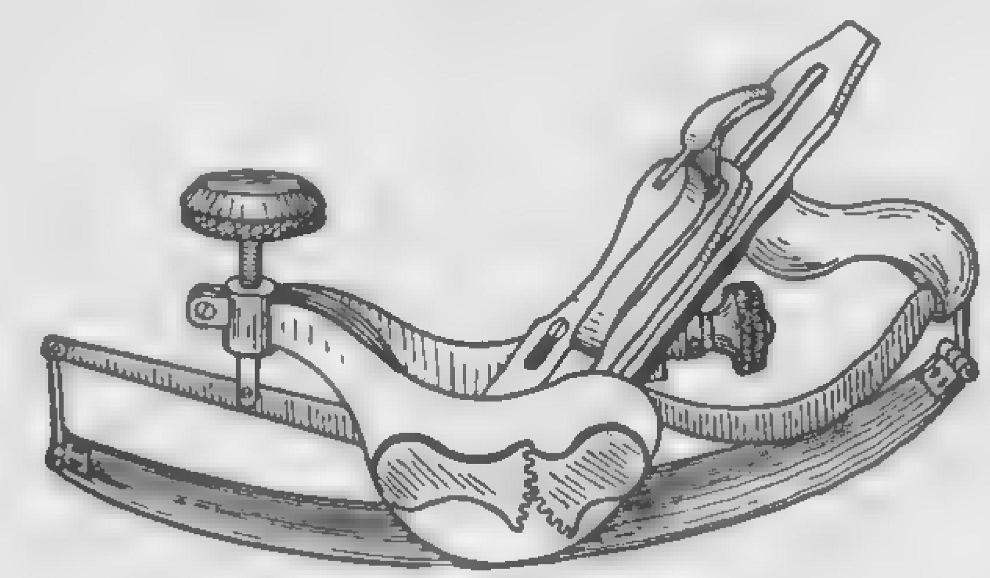


Fig. 26. Circular Plane

thick shaving without grooving at the edges. This plane works rapidly and easily, preparing the rough-sawed surfaces of planks for the finishing planes.

*Circular Plane.* For truing and smoothing circular arcs and curves of all kinds, either convex or concave, there is no tool that equals the circular plane, illustrated in Fig. 26. This plane has a

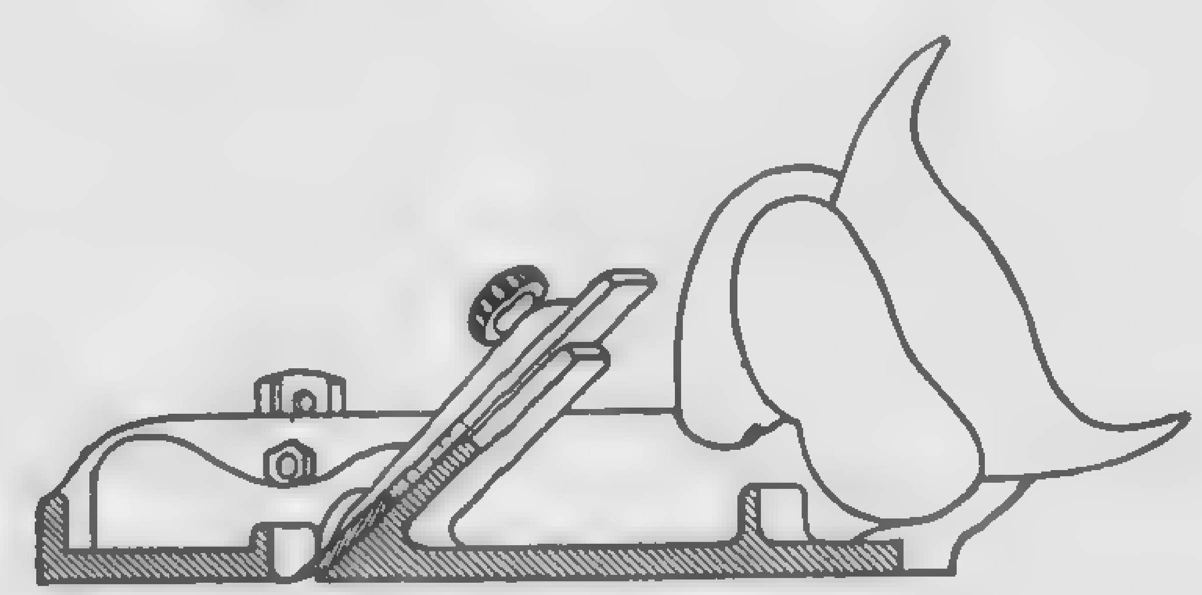


Fig. 27. Improved Rabbet Plane

flexible steel face which can easily be shaped to any required arc or curve by turning the knob on the front of the plane.

**Special Planes.** *Rabbet Plane.* Among the special planes used by the pattern maker, the rabbet plane, illustrated in Fig. 27, is the most important. The face of this plane is always flat and at right angles to the sides. It is used in working out square angles and corners, or *laps* as they are called in carpentry, and also for working

the lap joints, as shown in Fig. 28. It is fitted with depth gage, and also with a spur cutter, both of which are often of great convenience to the workman.

The skew-iron rabbet plane, in which the cutting edge of the plane iron is set diagonally across the face of the plane, works much

Fig. 28. Rabbeted Lap Joint

more smoothly and easily than one in which the iron is set at right angles to the side of the plane. Rabbet planes are made in sizes ranging from $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches in width. The 1-inch and $1\frac{1}{4}$-inch are convenient sizes for general work. In order to keep the plane cutting in the corner of the lap or square angle, a very definite pressure should be applied to the side of the plane.

*Universal Planes.* The assortment of planes for special shapes and curvatures which used to form part of the woodworker's tool kit has been replaced by universal planes which mount cutters of almost every shape. The planes are equipped with guides that are adjustable so that the plane can be used on either side of the work. With these tools, hollows and rounds of a range of radii, tongue and groove, slitting, molding shapes, and many other shapes can be readily cut.

**Spokeshave.** The spokeshave is used by the woodworker for shaping and rounding out small curves, either convex or concave, which cannot be reached with the circular plane. It can be found in a great variety of styles, either entirely in metal, as shown in

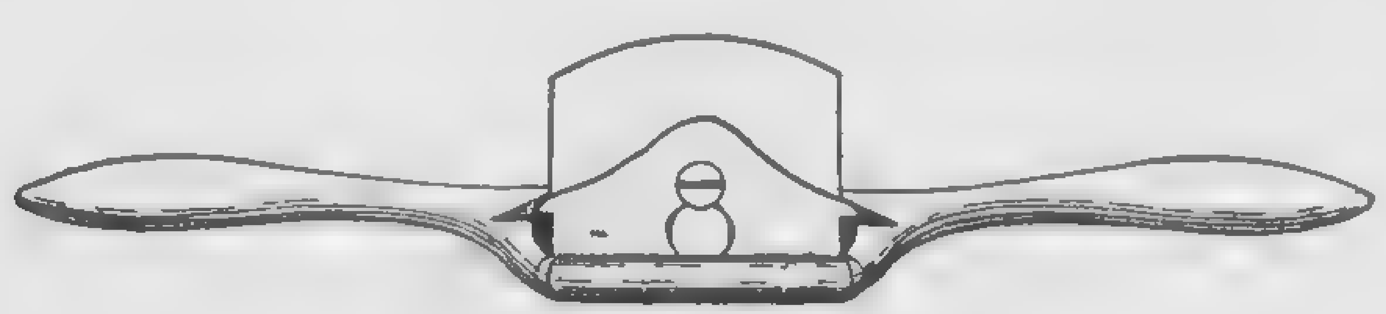


Fig. 29. Iron Spokeshave

Fig. 29, or with a wood bottom. The latter is to be preferred for the pattern maker's use, especially for working pine or other soft woods, since it is much less likely to mar them.

**Chisels.** The chisel enters so largely into the work of the woodworker in paring, and also in shaping, that the quality of the tool





should be of the best. While carpenters' chisels are made in several styles, they may be divided into two general classes: socket-handled chisels; and firmer or paring chisels. The former are illustrated in Fig. 36, and are used for framing, and for very heavy work of all kinds in which the use of a mallet is necessary.

*Common Paring Type.* The common firmer or paring chisels, two styles of which are shown in Fig. 37, are the best all-around

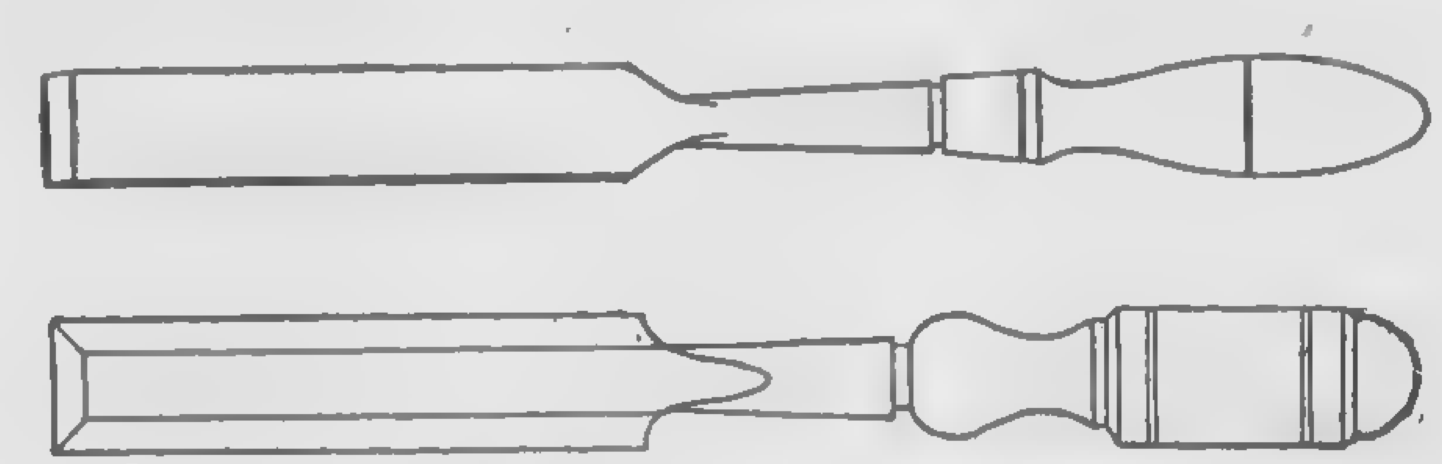


Fig. 36. Socket-Handled Chisels

chisels for woodworking. Being lighter and thinner than the others, they are better adapted to the light work on which they are used; moreover, when used with care, they will answer every desired purpose, even for heavy work or with a mallet. The beveled-edge chisel shown at *a*, Fig. 37, is greatly to be preferred. It is lighter than the other kind illustrated, and, the square angle being removed,

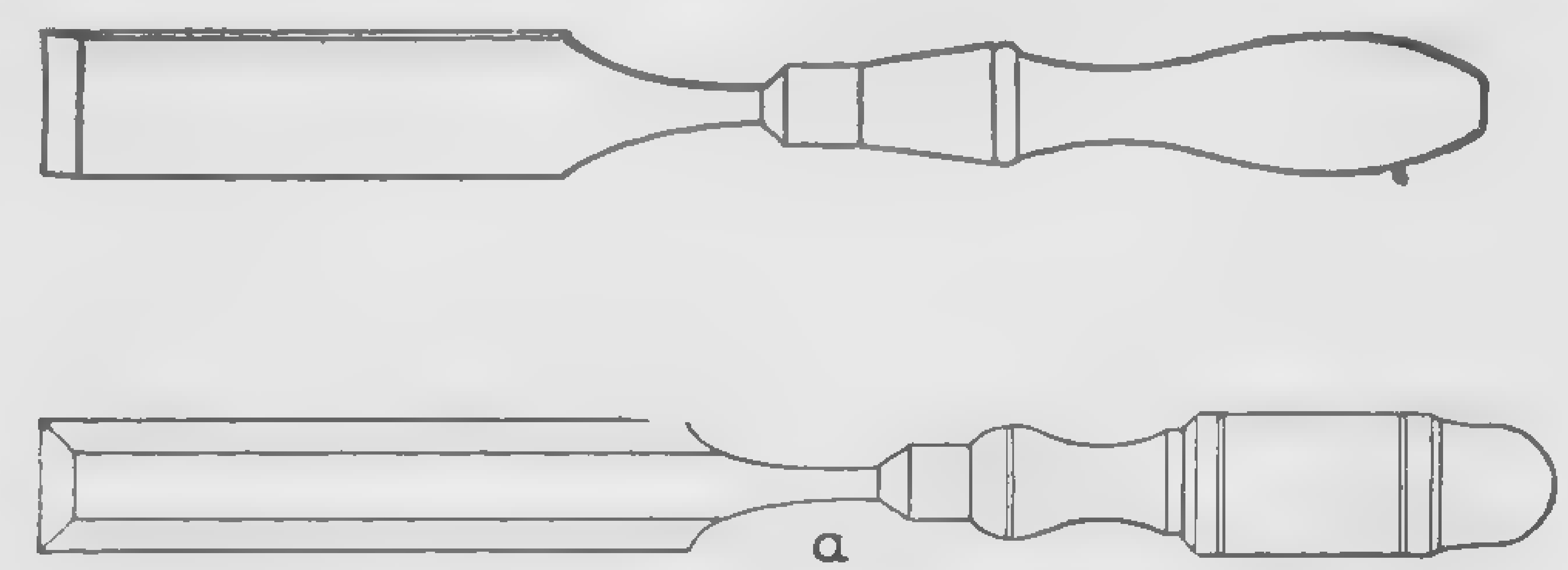



Fig. 37. Paring Chisels

the workman is enabled to reach into angles and under projections difficult to reach with a square-edged tool. A set varying in width from $\frac{1}{8}$ inch to $\frac{5}{8}$ inch by eighths, and from $\frac{3}{4}$ inch to $1\frac{1}{2}$ inches by quarters, nine chisels in all, will be found useful.

*Examples of Use.* The manner in which the chisel is used is so obvious and simple that any instruction in that direction would seem unnecessary. We shall only say in a general way that, in using

a chisel on a flat surface or in a recess, it should always be held with the flat or back of the chisel against the work, and, whenever possible,

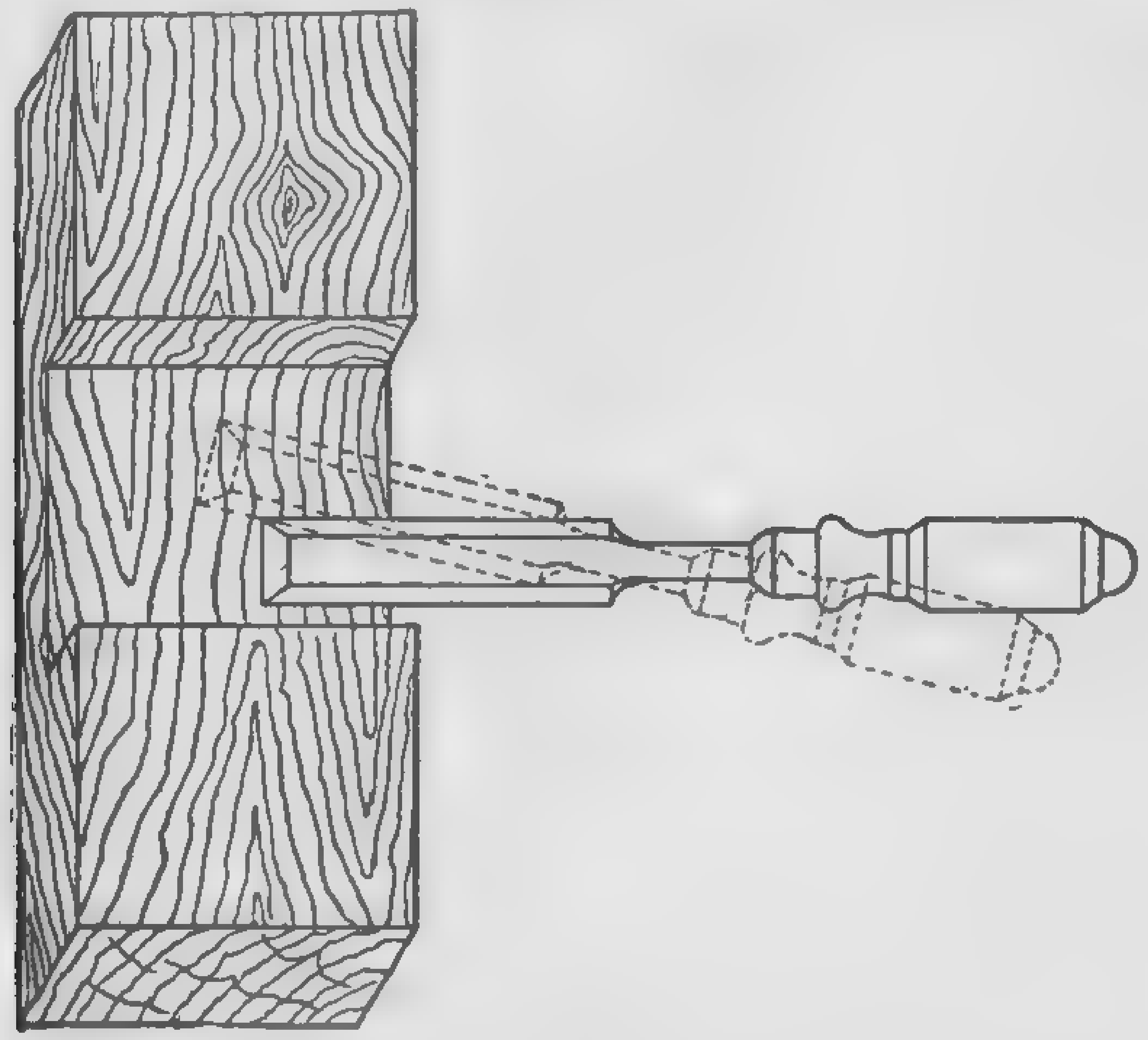


Fig. 38. Method of Using Chisel

it should not be pushed straight forward or straight through an opening, especially when paring across the grain of the wood, but should be moved laterally at the same time that it is pushed forward, as indicated by the dotted lines in Fig. 38. This insures a shearing cut, which, with care, even when the material is cross-grained, will produce a smooth and even surface.

As an exercise for acquiring the free use of the paring chisel, there is nothing better for the beginner than the simple half-lap joint shown in Fig. 39.

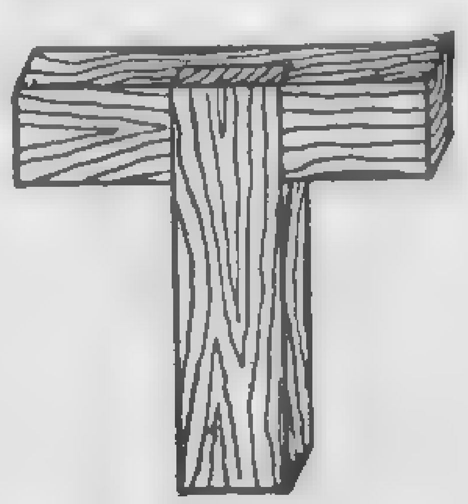


Fig. 39. Half-Lap Joint

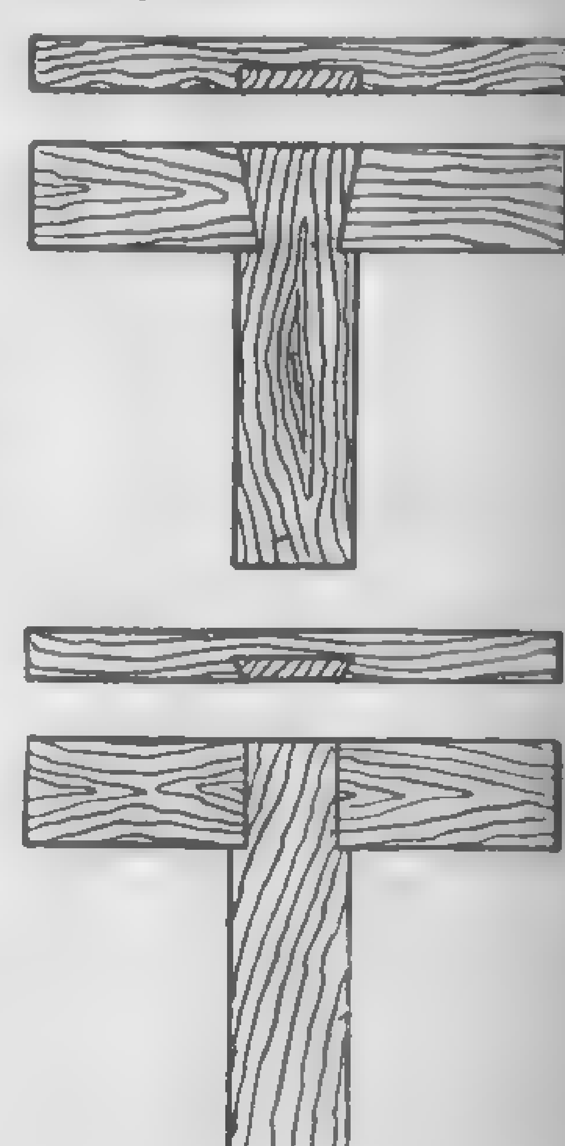


Fig. 40. Dovetail Joints

The shoulders or the ends of the openings must be cut with a back saw. The opening is then cut out and the shoulders





smoothed with a wide chisel, and a perfect fit obtained by continued trials.

The two dovetail joints, shown in Fig. 40, may be attempted after having succeeded with the half-lap; and these exercises should be continued by the student until such control of the chisel is attained that this and similar work can be done with ease and certainty. For laying out work of this kind the blade of a pocket-knife or bench knife should always be used. This gives a clean sharp cut angle for the meeting sides of the joints, which cannot be obtained if a scratch awl is used. The awl tears and breaks the fibers of the wood, producing a rough ragged angle, which, on fitting, cannot produce a smooth and close piece of work. A pencil is equally objectionable because of the indefinite dimensions given by its use.

**Gouges.** The paring gouges used in working on wood are ground or beveled on the inside, as shown in Fig. 41. These gouges are made

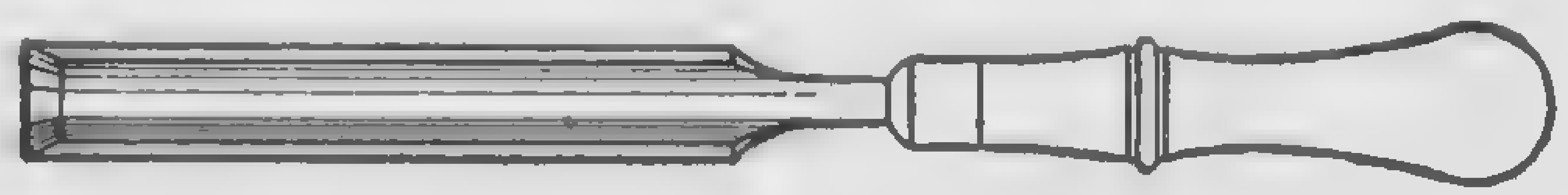


Fig. 41. Paring Gouge

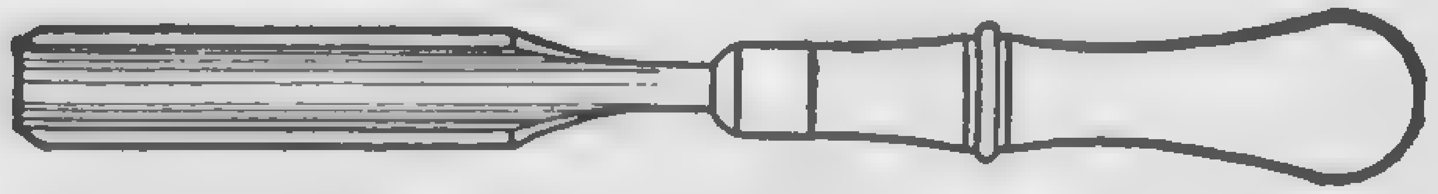


Fig. 42. Common Firmer Gouge

in regular, middle, and flat sweeps. They are indispensable for working out curves or holes.

In selecting a set of paring gouges, they should be not only of assorted sizes, but of different sweeps, so as to work out semicircles and curves of different radii.

The common firmer gouge, illustrated in Fig. 42, is a useful tool for rough or heavy work, and is a tool commonly found in the carpenter's kit.

*Front Bent Type.* An assortment of four to nine carver's gouges, front bent, as shown in Fig. 43, will be found necessary for working out short deep curves, and in places where a straight gouge cannot

be used, as in scrolls and other forms common to the woodcarver's art.

The full set consists of nine tools, the curves of which are numbered from *24* to *32*. The two extremes, Nos. *24* and *32*, are

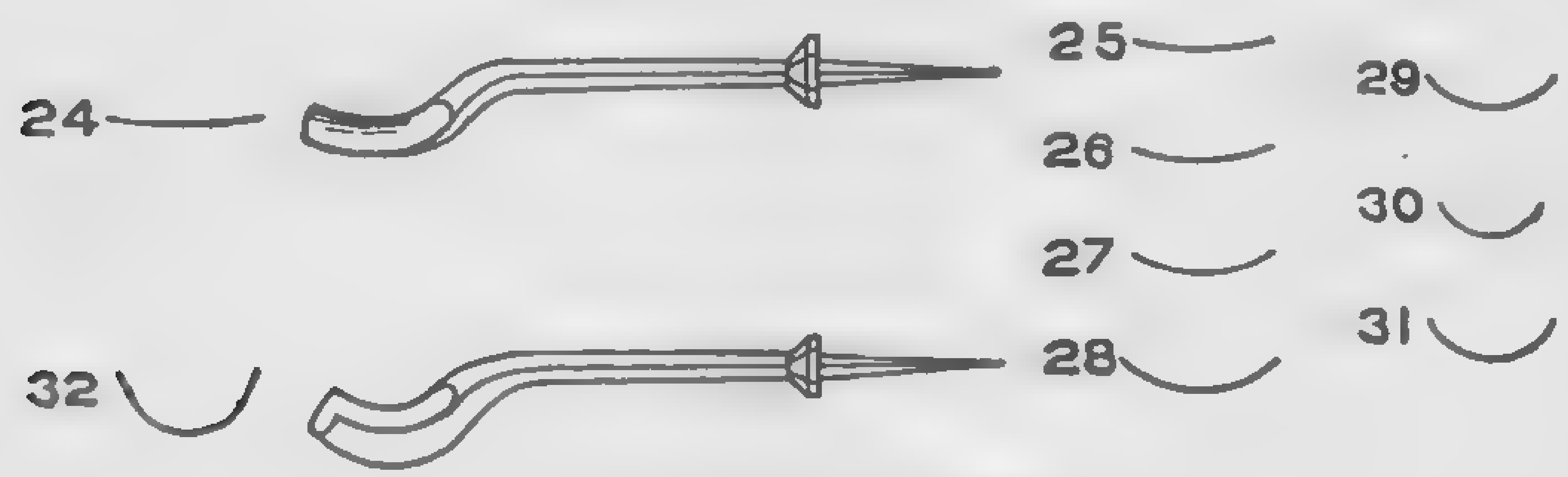



Fig. 43. Carver's Gouges

shown in Fig. 43, and also the shapes of the curves of the seven intermediate, Nos. *25* to *31*, inclusive. If desired, to save expense, each alternate tool might be omitted from the set, only the odd numbers *25*, *27*, *29*, and *31* being selected, and for ordinary work these will be found sufficient.

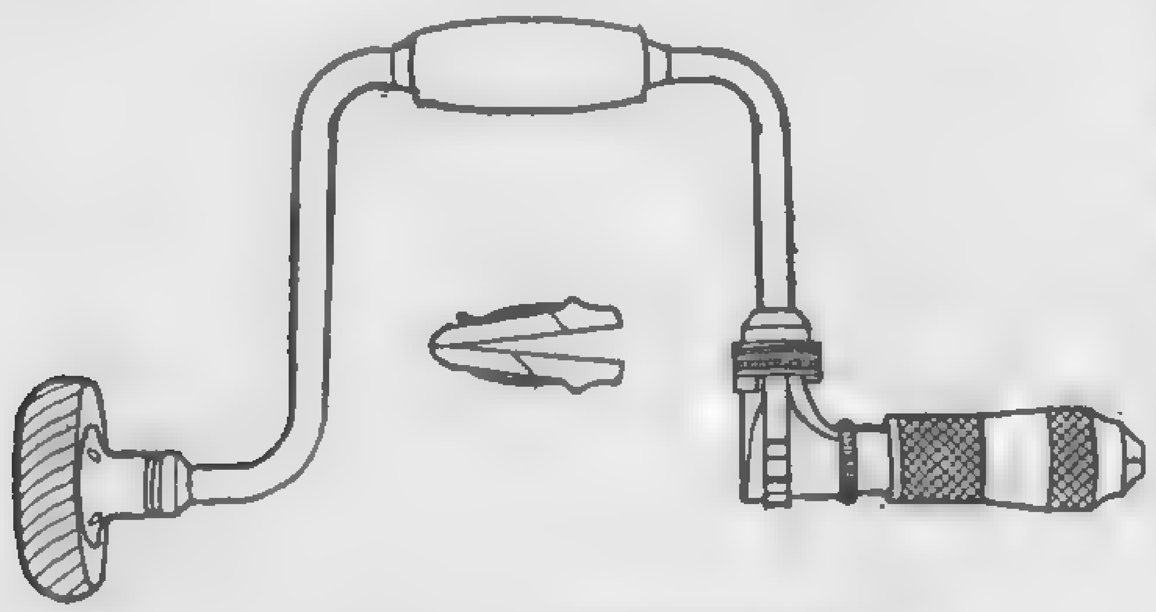


Fig. 44. Ratchet Brace

**Boring Tools.** *Brace.* Among the necessary tools are the brace and an assortment of boring bits. The most desirable style of brace is the ratchet brace, illustrated in Fig. 44. The convenience of the ratchet will soon be apparent from the necessity, so often arising, for boring holes or driving screws in angles or close to projections where the full sweep of the brace cannot be taken. Braces are made in many sizes, with sweeps varying from 6 inches to 14 inches in diameter.

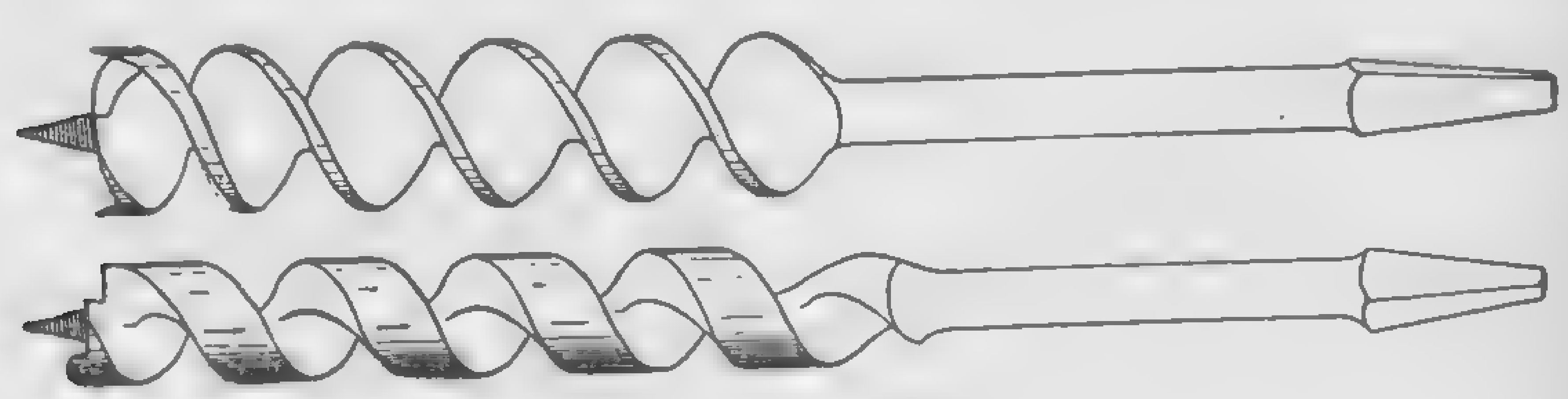


Fig. 45. Auger Bits





A brace with an 8-inch sweep is the most convenient in size for boring holes 1 inch or less in diameter in soft wood. For larger holes, and especially in very hard woods, a 10-inch or 12-inch sweep is necessary.

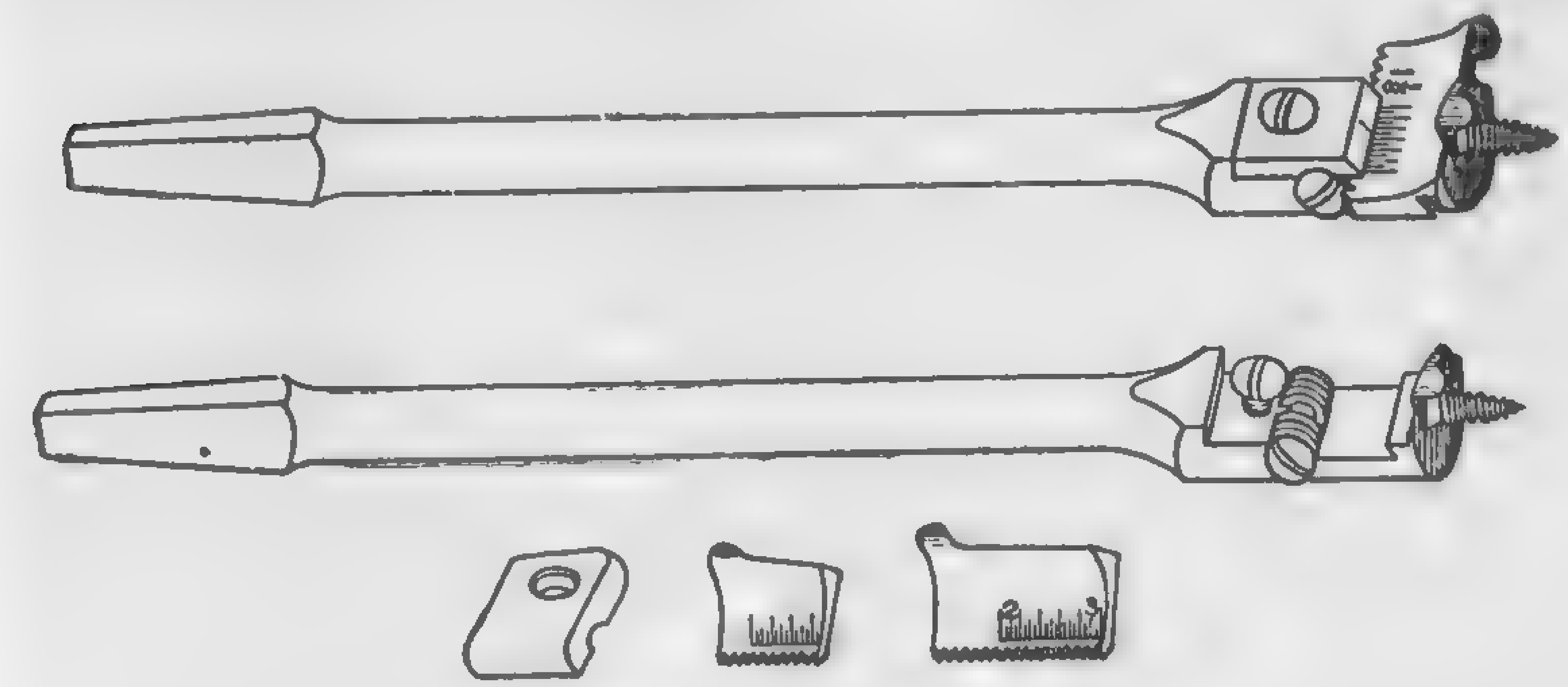


Fig. 46. Extension Bit

*Bits.* Wood-boring bits are made in many styles. The most important are the auger bits, two styles of which are shown in Fig. 45. They can be bought in sizes running by sixteenths of an inch from $\frac{3}{16}$ inch to 1 inch. For holes larger than 1 inch, the No. 2 extension bit, shown in Fig. 46, is the best. It has two cutters, and will bore a hole of any size from $\frac{7}{8}$ inch to 3 inches in diameter.

Fig. 47. Gimlet and Wood Drill

For screw holes, the gimlet bit or the twist drill for wood, both of which are illustrated in Fig. 47, are used. They can be bought in all sizes running by thirty-seconds of an inch from $\frac{1}{32}$ inch up to $\frac{3}{8}$ inch.

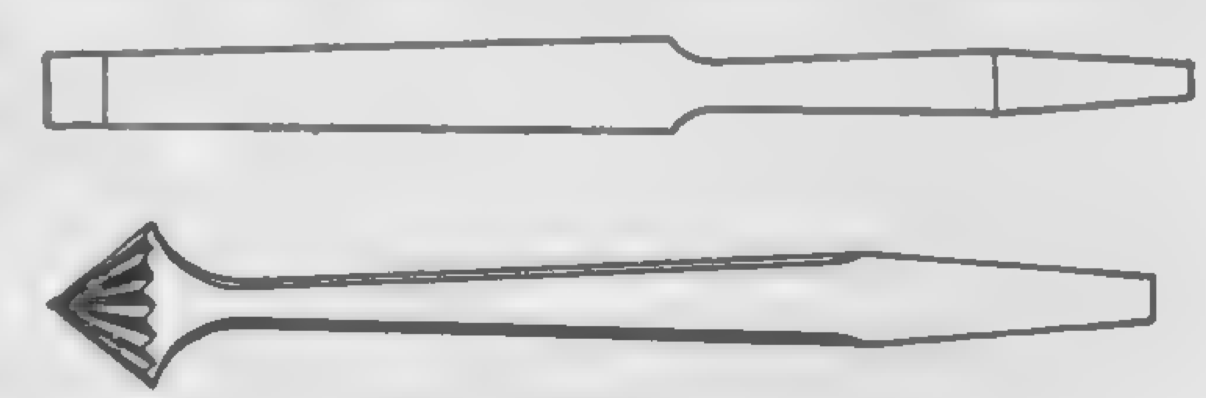


Fig. 48. Brace Screwdriver and Countersink

The brace screwdriver, and also the brace countersink for screw heads, are important tools. They are shown in Fig. 48, and can be bought in large, medium, and small sizes.

## MEASURING TOOLS

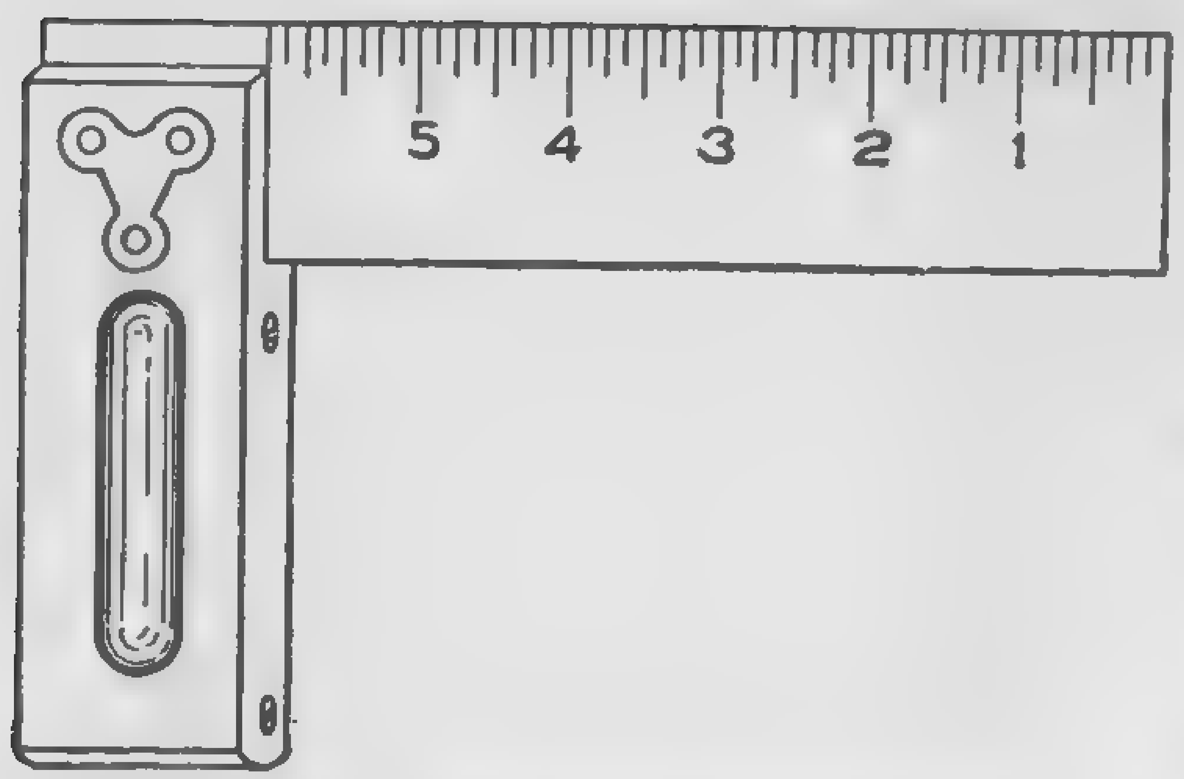


Fig. 49. Try Square with Fixed Blade

**Squares.** The best try squares are now made with blades graduated, and from 2 inches to 12 inches in length. Several sizes of the fixed-blade type, Fig. 49, are needed, as in many cases the blade must be short to admit of its application to the work.

**Steel Squares.** Fig. 50 shows the shape and illustrates in a general way how it is used. The square is comparatively thin, yet is not flexible. It has two arms or blades which meet at right angles. The longer, wider part is called the *body* or *blade*; the shorter, narrower part is the *tongue*. In the standard size, the blade is 24 inches long and 2 inches wide, the tongue is 16 inches long and $1\frac{1}{2}$ inches wide.

The outside corner where blade and tongue meet is called the *heel*. The inside corner is also sometimes called the *heel*. The manufacturer's name is always on the *face*; the other side is the *back*.

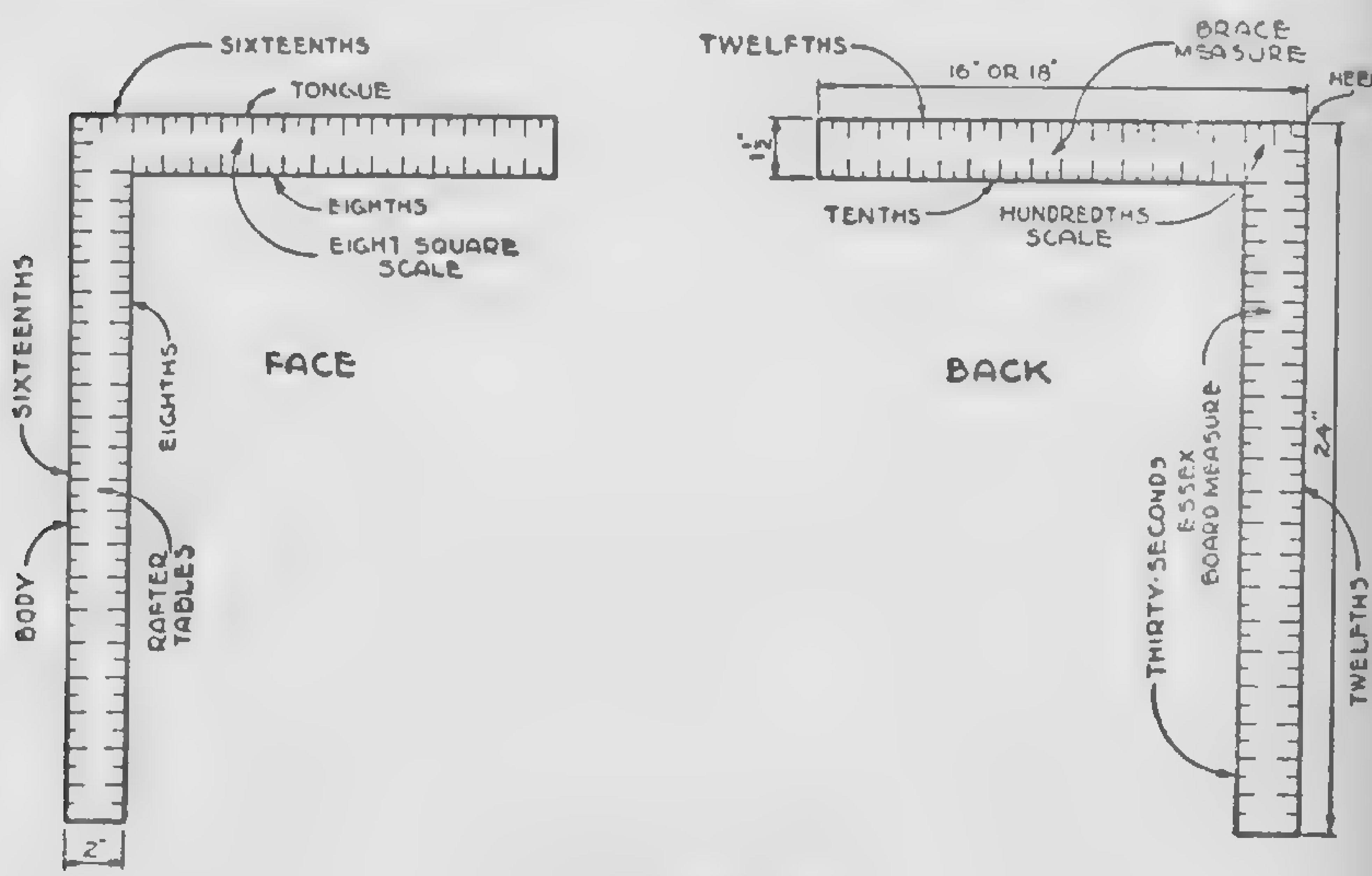



Fig. 50. Steel Square





**Bevels.** The bevel illustrated in Fig. 51, with the clamping screw in the end of the handle, is the most accurate and the most easily adjusted style of this indispensable tool. The blades are made from 6 to 12 inches in length, and have a slot in at one end, which admits of that end being adjusted to meet the requirements of the work.

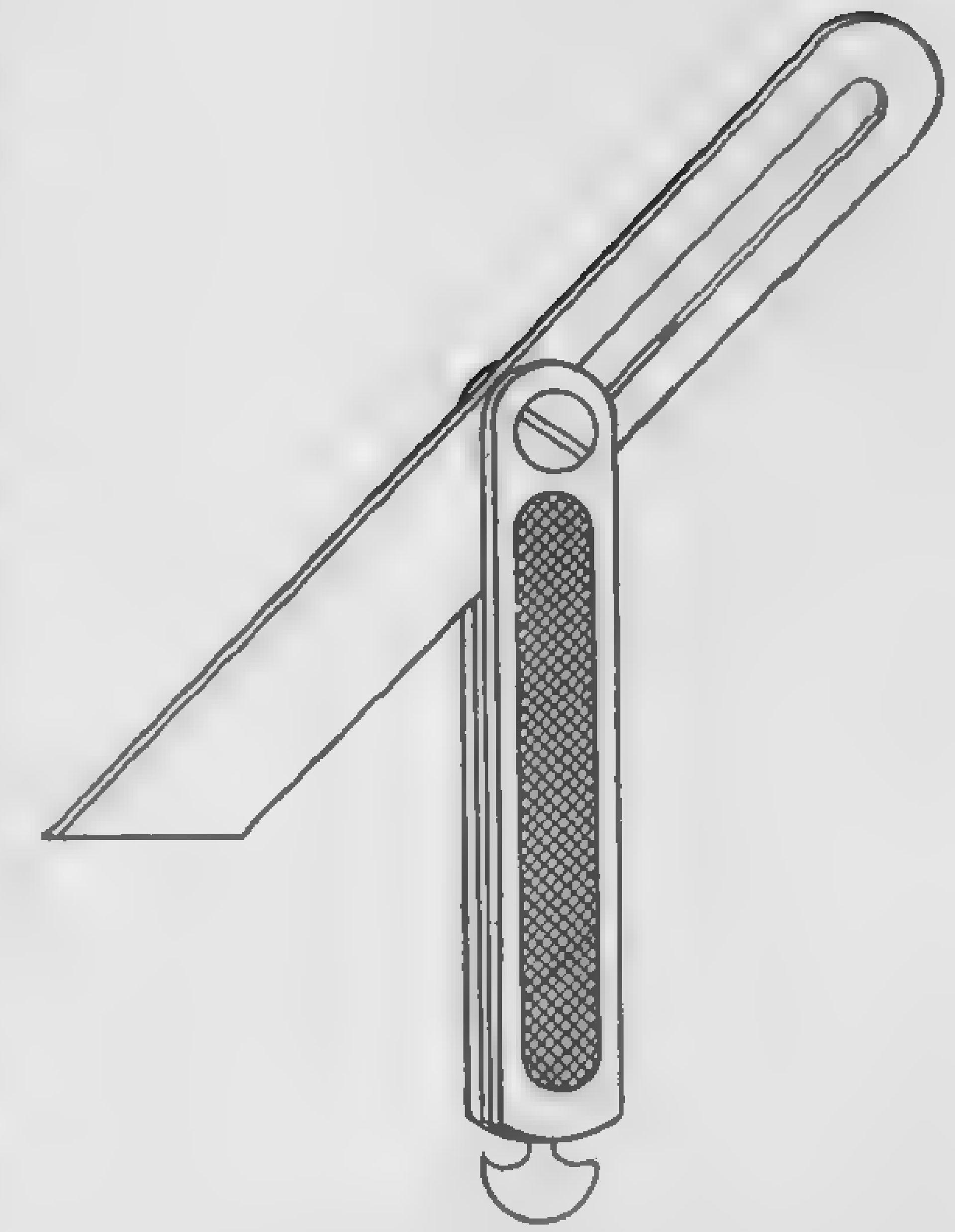


Fig. 51. Bevel

**Rules.** For all ordinary measurements, a 2-foot folding rule, Fig. 52, will be sufficient, but a 6-foot zig-zag rule is standard.

**Marking Tools.** *Marking Gage.* The marking gage is used for drawing a line at a given distance from, and parallel to, the already trued and jointed surface or edge of a board or piece of wood that is being marked to dimensions.

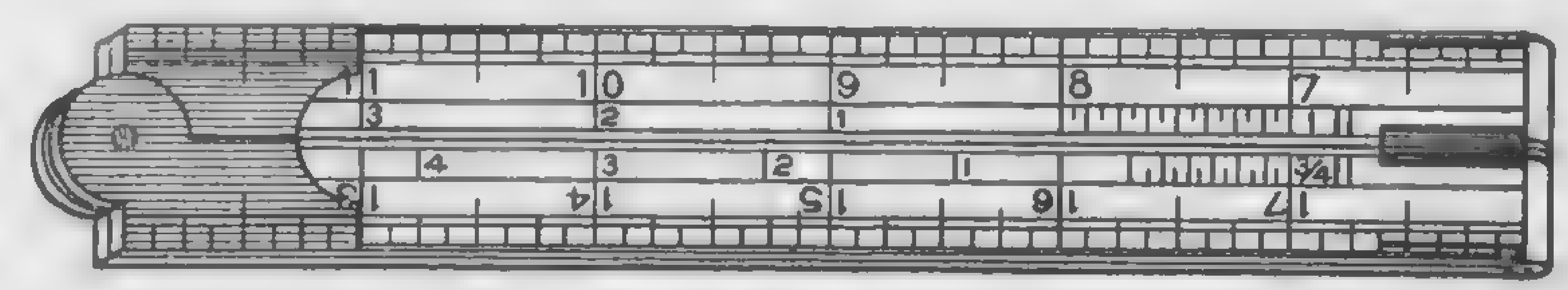


Fig. 52. Folding Rule

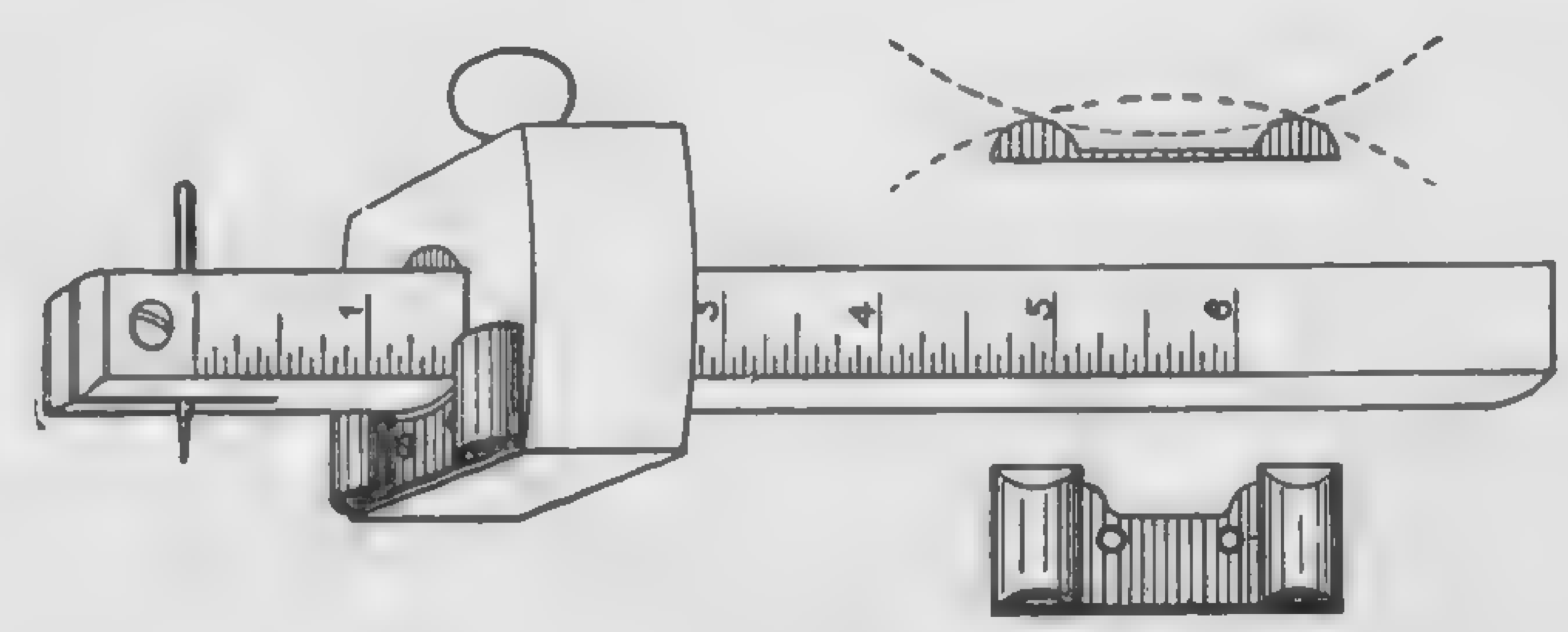


Fig. 53. Improved Marking Gage

There are many forms of this tool, but in the improved gage, illustrated in Fig. 53, the head is reversible. The flat side of the head is used for ordinary straight work, while the reverse side, hav-

ing the brass face with two projecting ribs, enables the operator to run a gage line with perfect steadiness and accuracy around curves of any radius, either convex or concave—a feature much to be desired.

*Dividers.* The ordinary woodworker's dividers can be bought in many forms, the most common being the screw-adjusting wing dividers shown in Fig. 58. This form is reliable, and is easily adjusted to the required distance between points. Moreover, when

Fig. 58. Common Wing Dividers

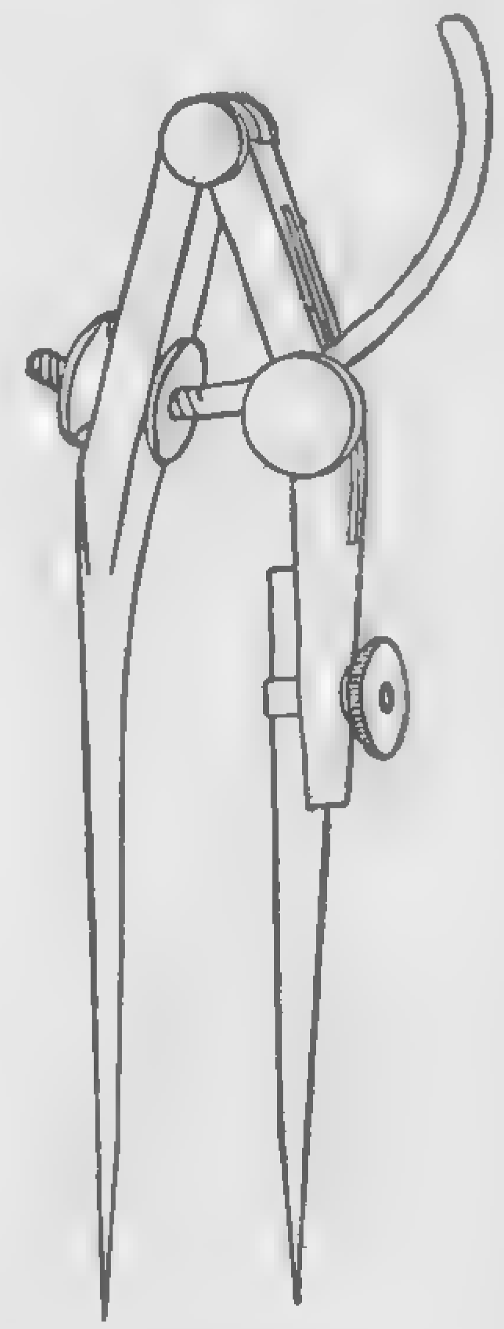


Fig. 59. Removable-Point Dividers

clamped by the thumbscrew, it is not liable to be altered by a slight blow in handling.

Another and improved form is shown in Fig. 59, one leg of which is removable so that a pencil can be inserted. This will be found very convenient for marking and laying out work.

For spacing the teeth of gear wheels, and for other work in which great accuracy is required, a pair of $2\frac{1}{2}$-inch or 3-inch dividers, such as are shown in Fig. 60, will be found necessary.

*Trammel.* The trammel is used when the distance between the points to be reached is too great for the ordinary dividers. The trammel points are clamped to a beam of sufficient length to enable them to be set the required distance apart. They may be bought





plain, as in Fig. 61, or with one point adjustable, as in Fig. 62. The points are removable for the insertion of a pencil socket and pencil when needed.

For very accurate work, an excellent tool of this kind is illustrated in Fig. 63. The beams furnished are 4 inches and 13 inches in length. By the use of the cone center *V*, which may be substituted for the regular point center, the tool can be used for scribing a line around any hole already bored —sometimes a matter of great convenience. The complete set includes

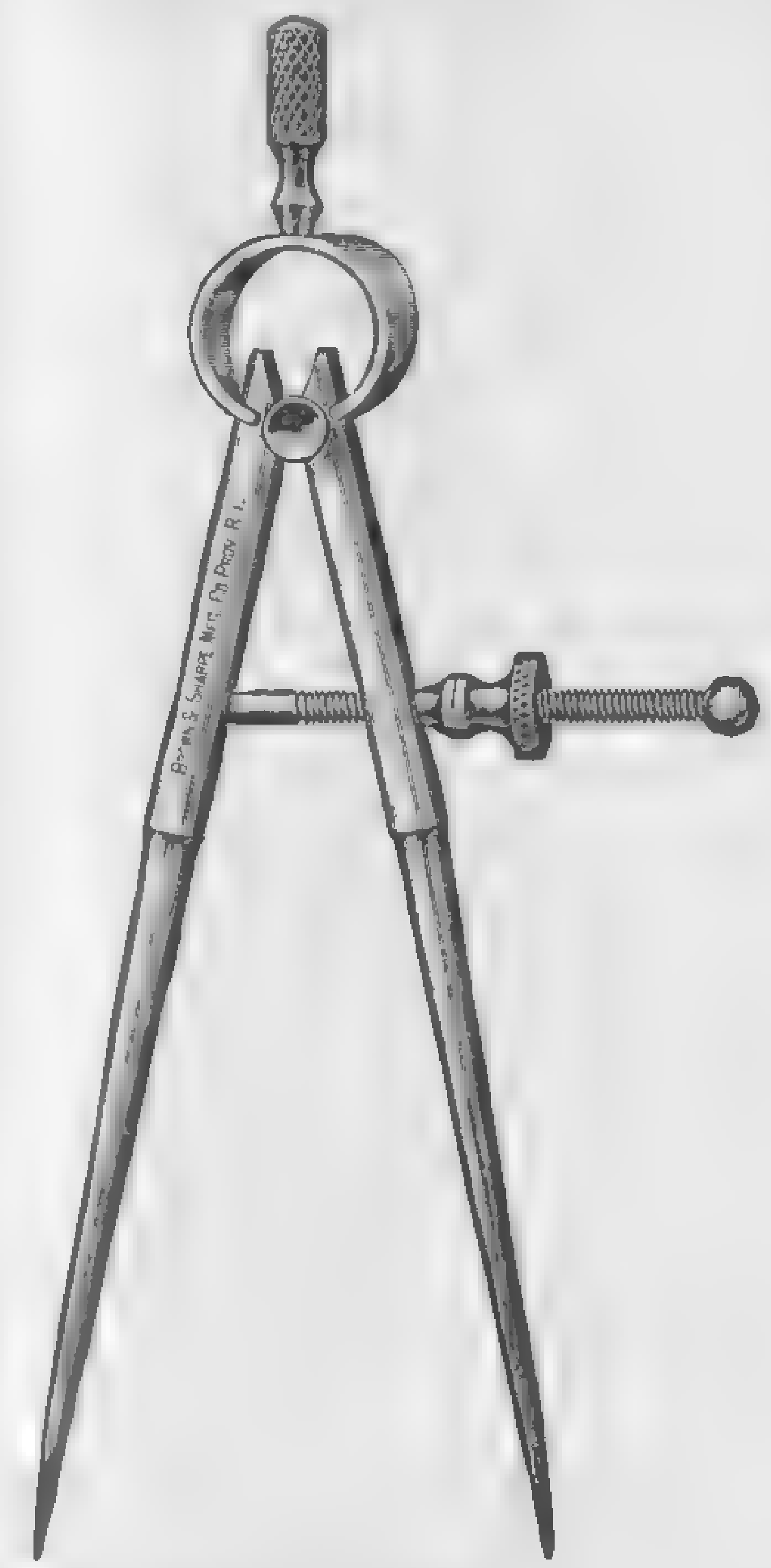


Fig. 60. Brown and Sharpe Spring-Joint Dividers

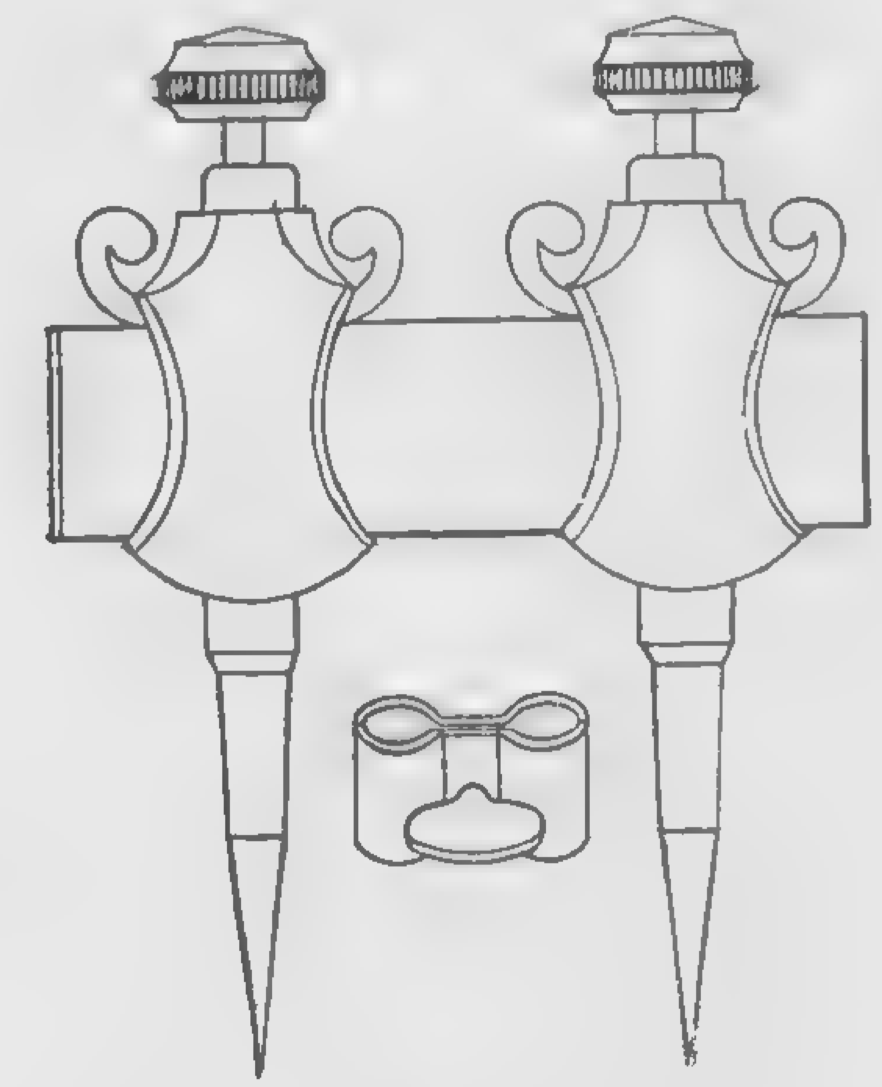


Fig. 61. Plain Trammel Points

the pen, pencil, straight and bent points, and the cone center, as shown in the cut.

**Calipers.** Calipers, like dividers, are made in many different forms with and without screw adjustment. Fig. 64 illustrates the screw-adjusting wing calipers for outside measurements, and Fig. 65 shows the firm-joint outside calipers used for the same purpose. Inside calipers for taking inside dimensions and inside distances are shown in Fig. 66, and the adjustable inside calipers are illustrated in Fig. 67.

Calipers are used for measuring the distances between points external and internal when a rule could not be used with accuracy.

They are indispensable to the wood turner for measuring the diameters of cylindrical forms and other work while being turned to

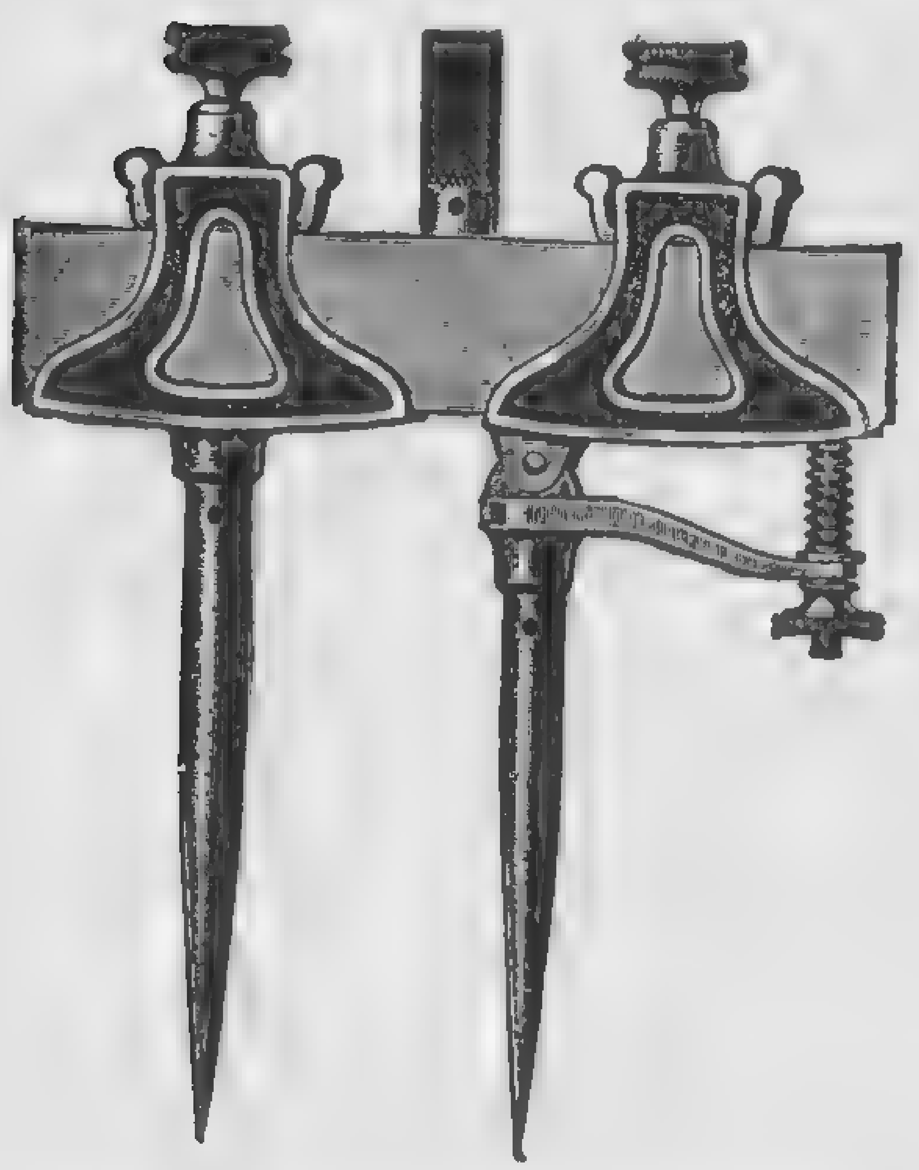


Fig. 62. Trammel with Adjustable Points

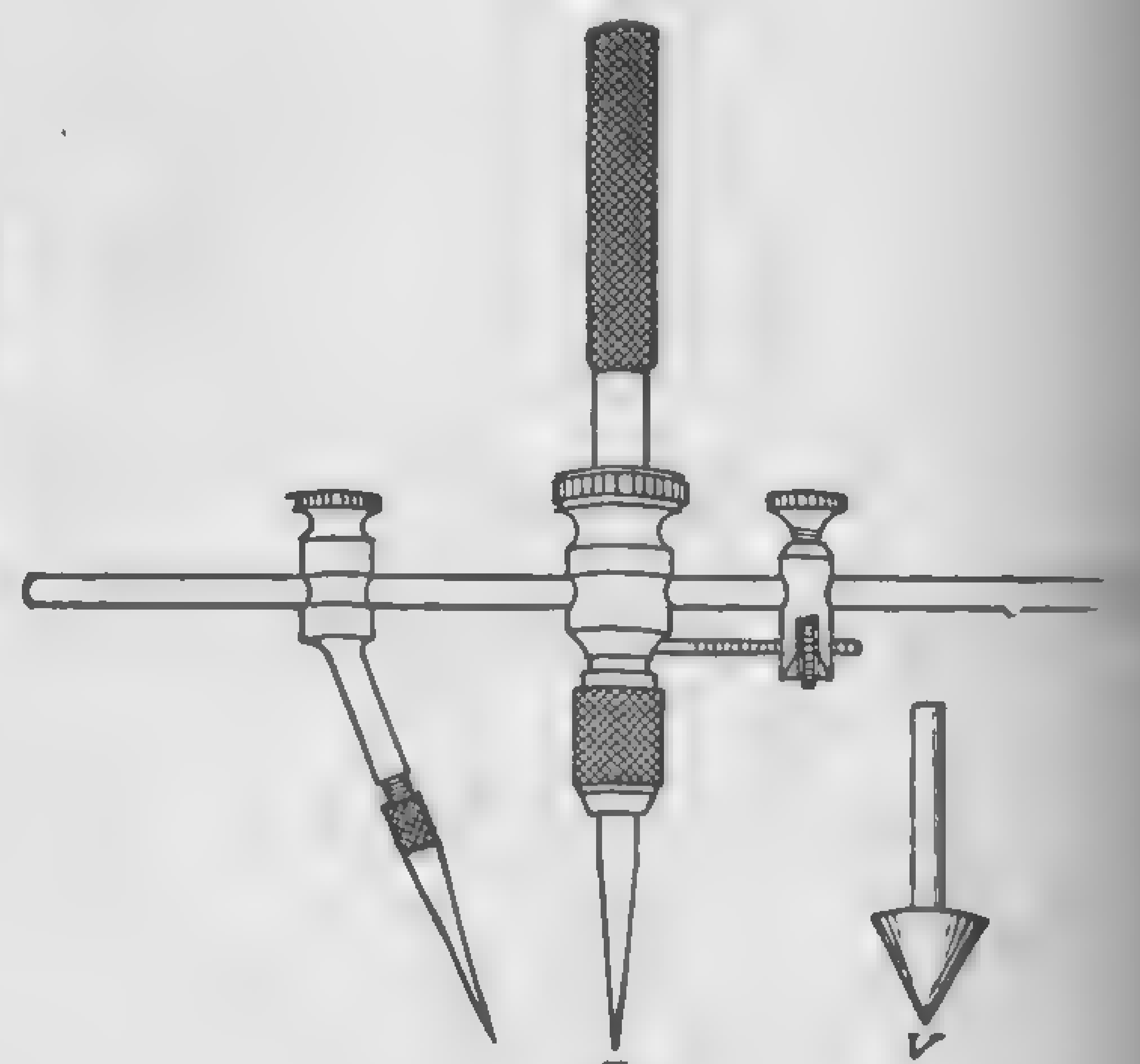


Fig. 63. Accurate Trammel Set

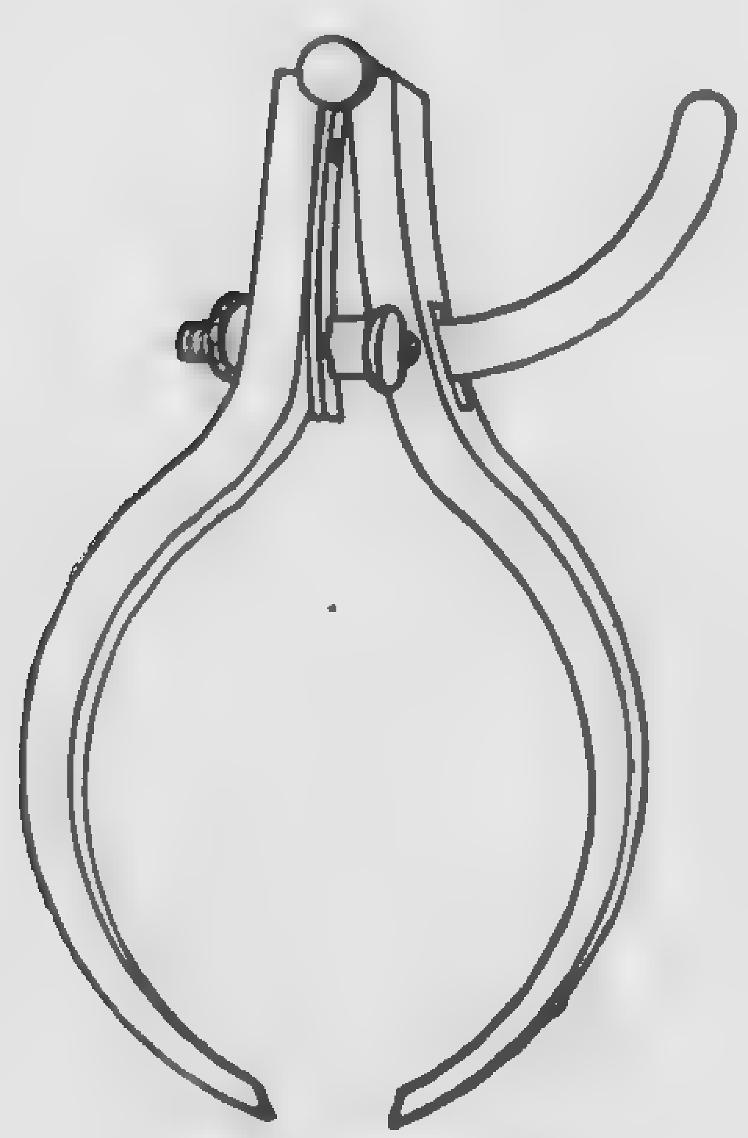


Fig. 64. Wing Calipers

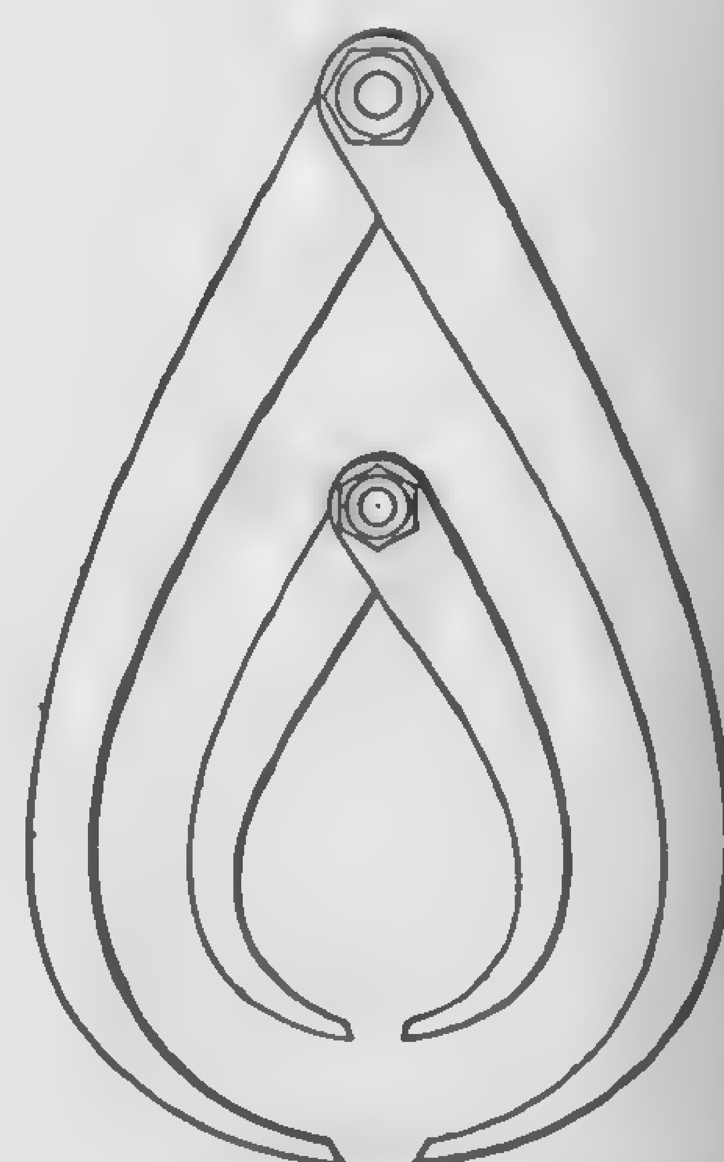


Fig. 65. Firm-Joint Calipers

required dimensions in the lathe. When used by the pattern maker, they may be applied while the wood is revolving, until it has been





reduced almost to the required dimensions; after which, when the calipers are used, the lathe should be stopped to prevent the surface from being marked by the points, and in order to obtain exact measurements. The calipers should not be pushed or forced over the piece, but in passing over the finished cylinder, the points should

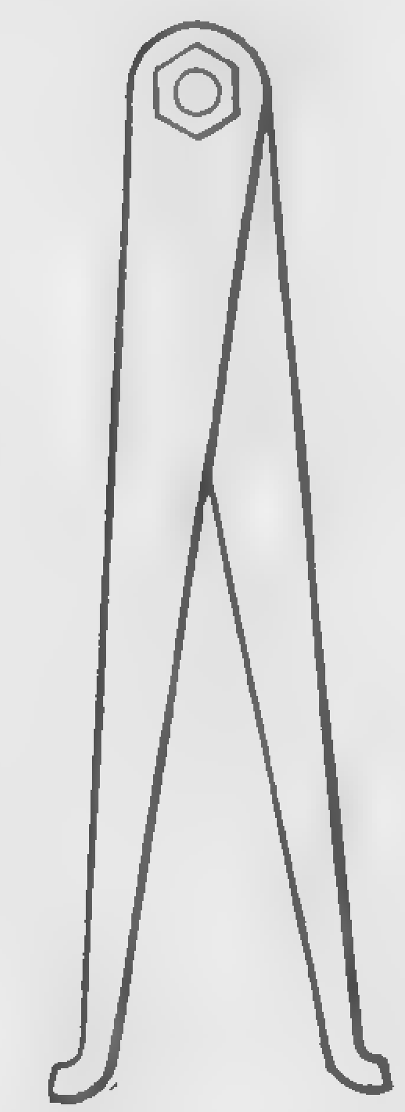


Fig. 66. Inside Calipers

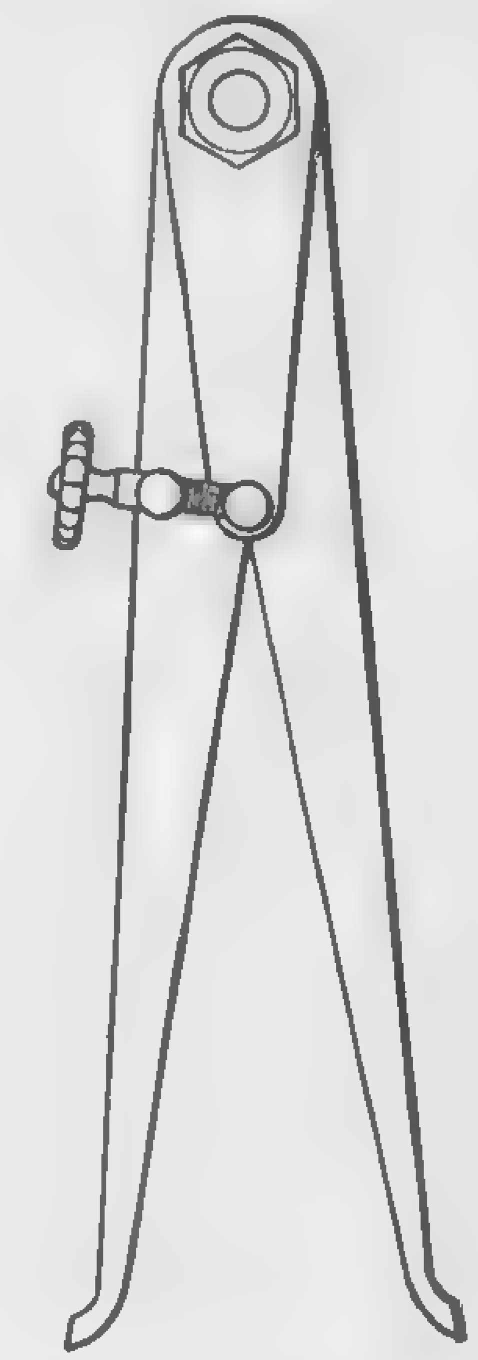


Fig. 67. Adjustable Inside Calipers

touch it lightly without springing the legs of the calipers; otherwise, the required dimensions cannot be obtained with accuracy.

## MISCELLANEOUS SMALL TOOLS

**Forcing Tools.** *Hammer and Mallet.* There remain to be described a few tools, which, while necessary, are so common as hardly to require either illustration or description. Among these are the hammer, the best form of which for use in woodworking is shown in Fig. 68, and the mallet, of which the best form is shown in Fig. 69.

A mallet that is to be used on the handle of firmer chisels and other tools for woodworkers should not be made of hickory or of lignum-vitae, nor have hard-rubber or hard-fiber facing. Mallets

thus made soon mar, splinter, and destroy the tool handles on which they are used. Beechwood and maple furnish the best material for mallet heads for the use of the woodworker who works

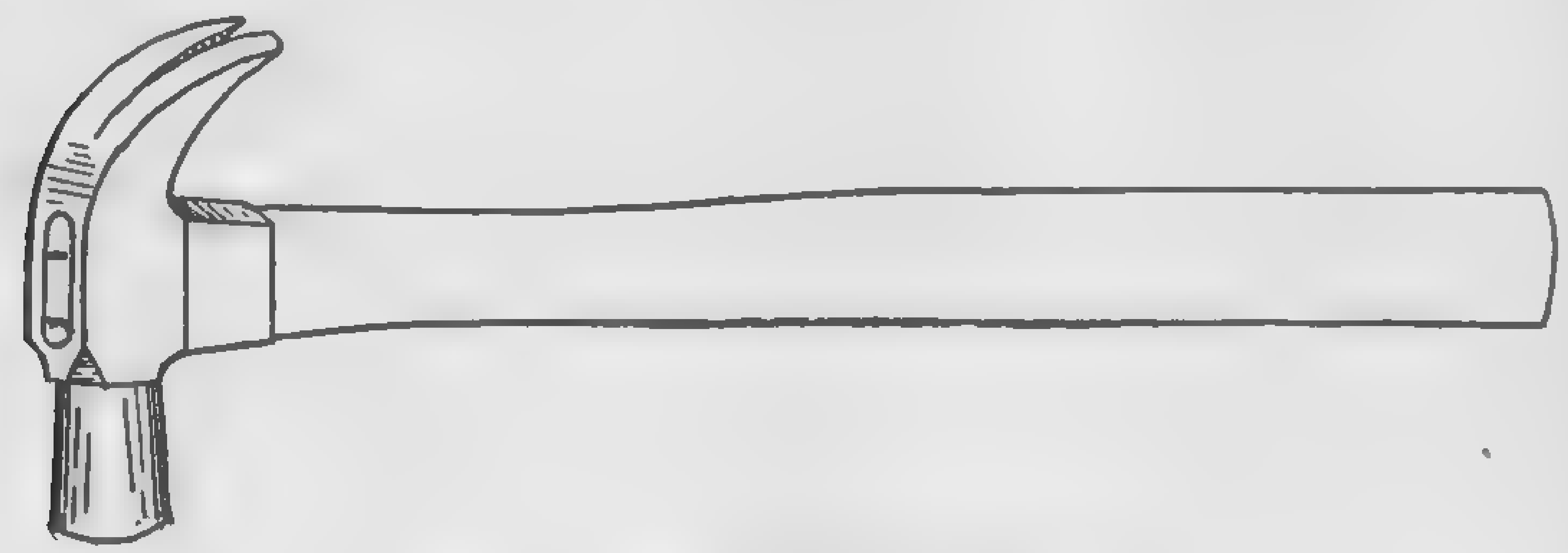


Fig. 68. Typical Woodworker's Hammer

in pine and other soft woods. It is true that the mallet head will not last so long if made of beech or maple wood, but the chisel and gouge handles will be protected, which is a matter of much greater importance.

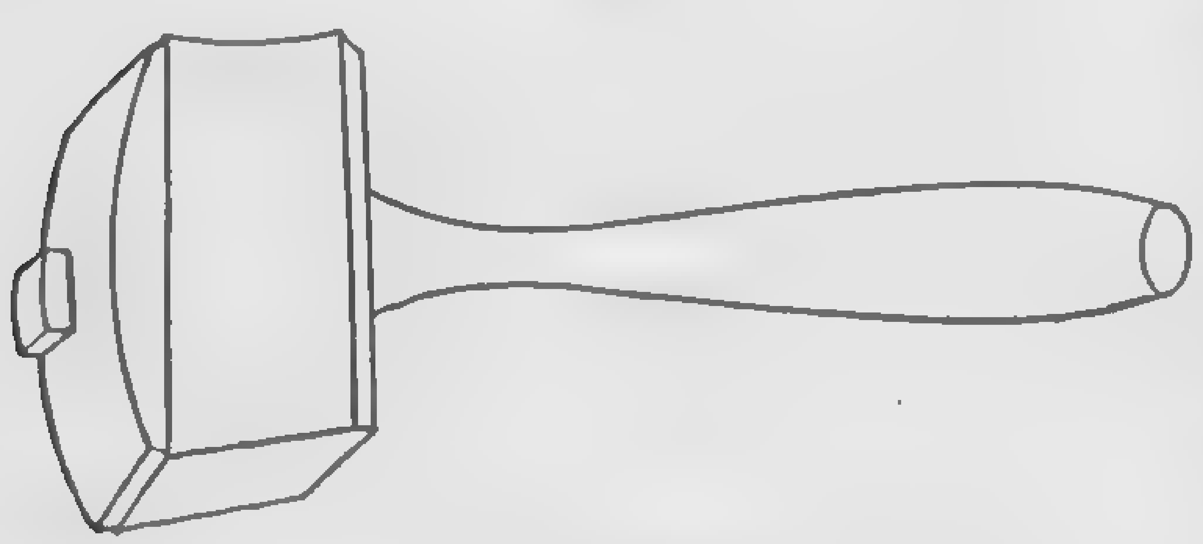


Fig. 69. Mallet

*Screwdriver and Awls.* Of the screwdriver, illustrated in Fig. 70, at least two or three sizes will be found necessary.

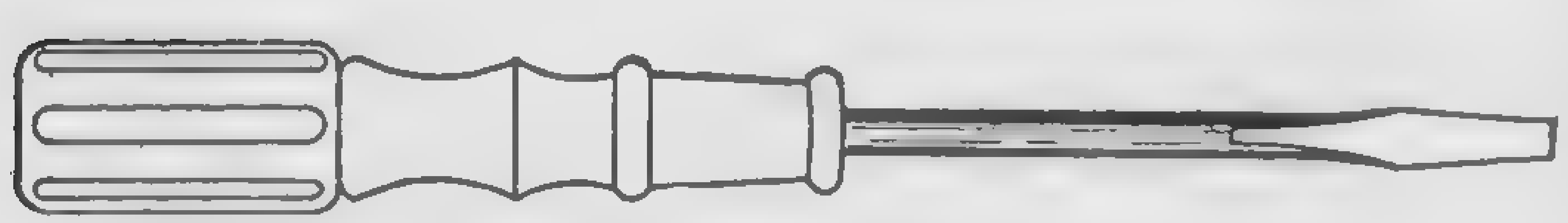


Fig. 70. Ordinary Screwdriver

The scratch awl, Fig. 71—although but little employed at the work bench, where a knife is used in its place for all accurate markings—is indispensable to the woodworker for laying out the dimensions on his work while it is revolving in the turning lathe. It should be long and slender, as shown, and is used on the revolving wood by placing it over the required graduation of the rule, while the latter is held on the tool rest.

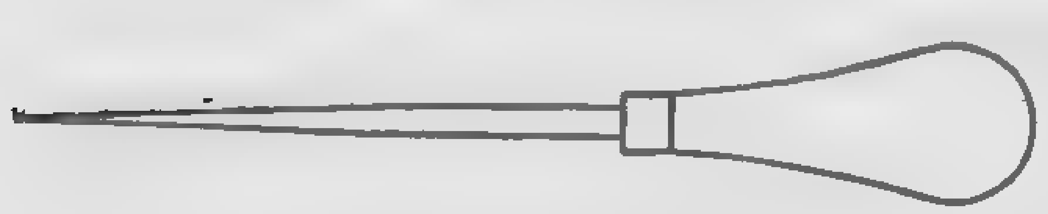


Fig. 71. Scratch Awl





Brads and small wire nails must often be driven at such an angle to the grain of the wood, or in such a position, as to make it necessary first to bore a small hole in order to start the brad in the required direction. The brad awl, illustrated in Fig. 72, is a convenient tool for this purpose. It is commonly ground to a chisel point, as shown at *a*, but will be less liable to cause splitting, and will work faster and with greater ease, if ground to a double spear point, as shown at *b*. The four corners, if kept sharp, will enter the wood and cut faster than the chisel point. Care must be exercised in placing nails so that the edges of tools will not come in contact on later machine or hand operations. However, nails or brads do not interfere with sanding operations on the vertical spindle or disk sanders.

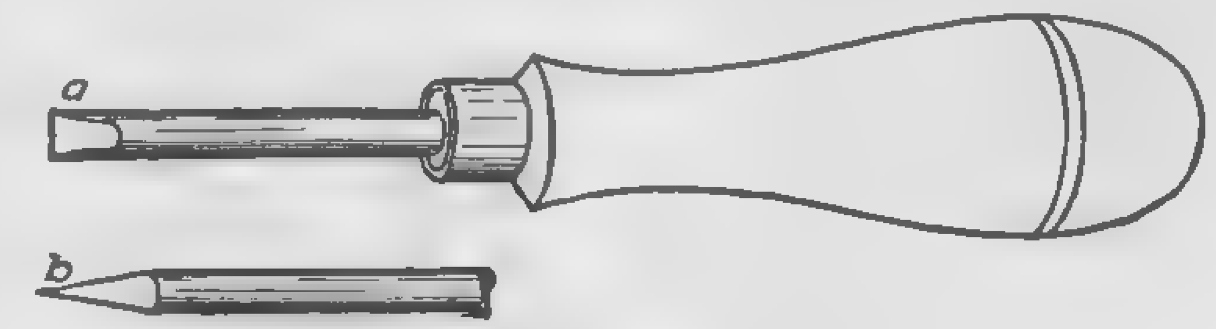



Fig. 72. Brad Awl

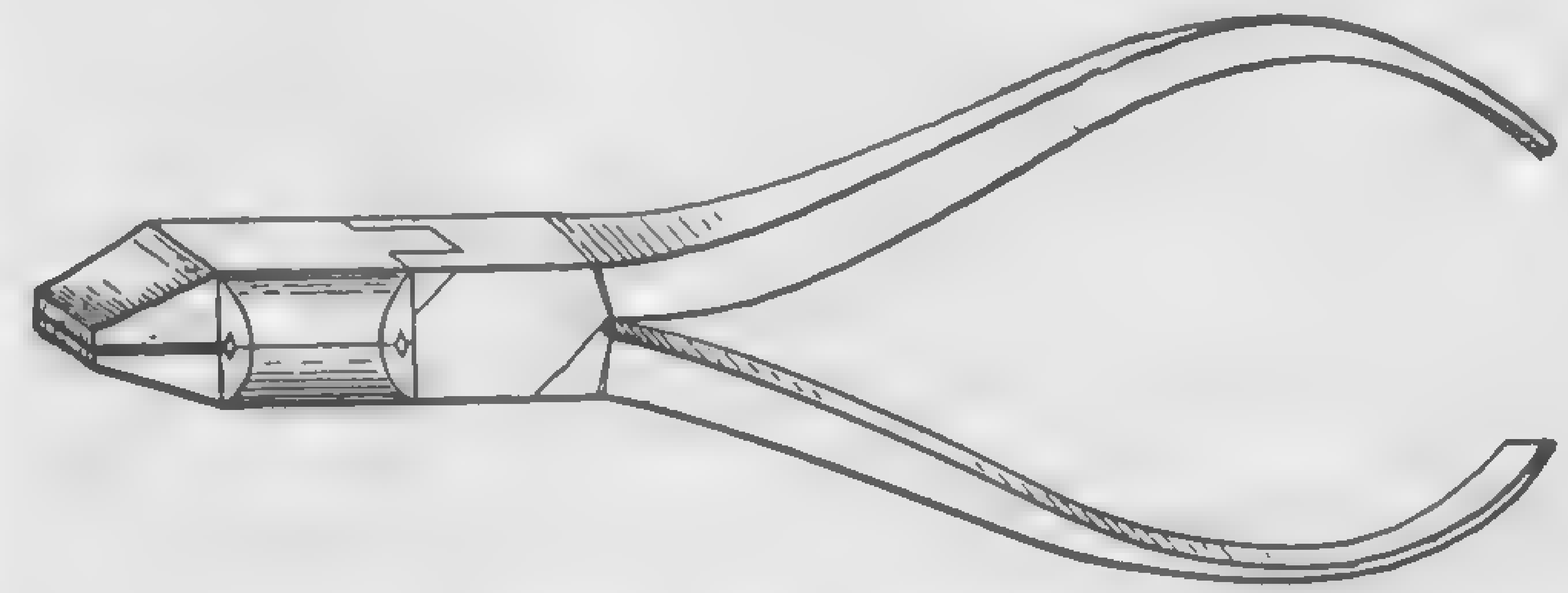


Fig. 73. Side-Cutting Pliers

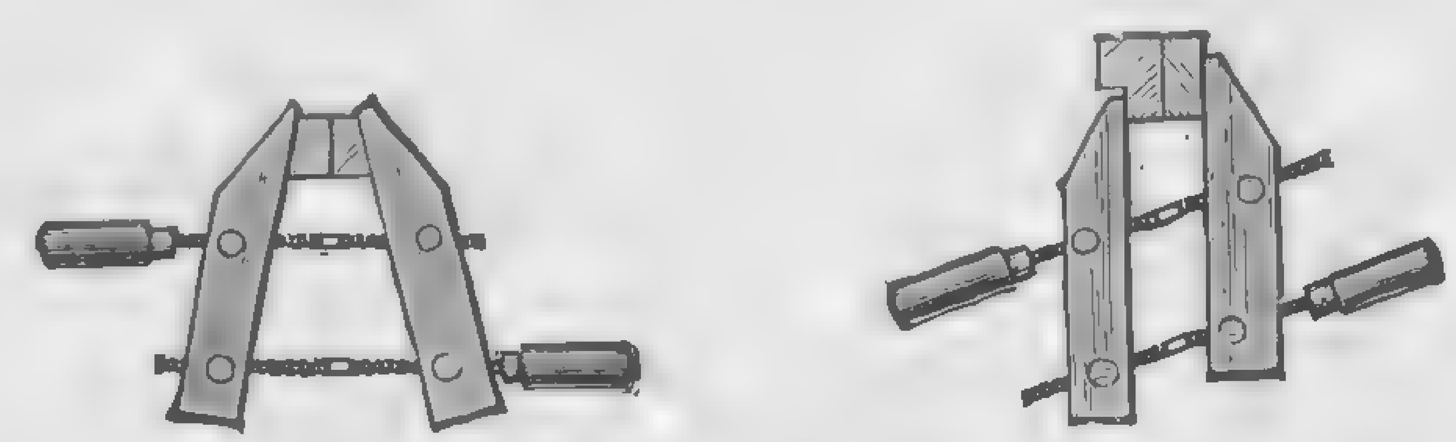


Fig. 74. Uses of Adjustable Screw Clamps
*Courtesy of Oliver Machinery Company, Grand Rapids, Michigan*

*Pliers and Clamps.* Side-cutting pliers, such as are illustrated in Fig. 73, will be found convenient not only for cutting off wire

and brads, but for removing small brads and for holding small pieces while being worked to shape.

Every pattern shop should have at least one dozen each of three or four different sizes of hand screws or clamps similar to that shown in Fig. 74. These are adjustable through wide ranges. They are used for clamping together the material that is being glued up to form the different parts of a pattern, and are convenient also for many other purposes. The all-iron **C**-clamp, shown in Fig. 75, is sometimes useful in positions that are hard to reach with a hand screw. The method of adjusting and of using the hand screw will be fully explained later.

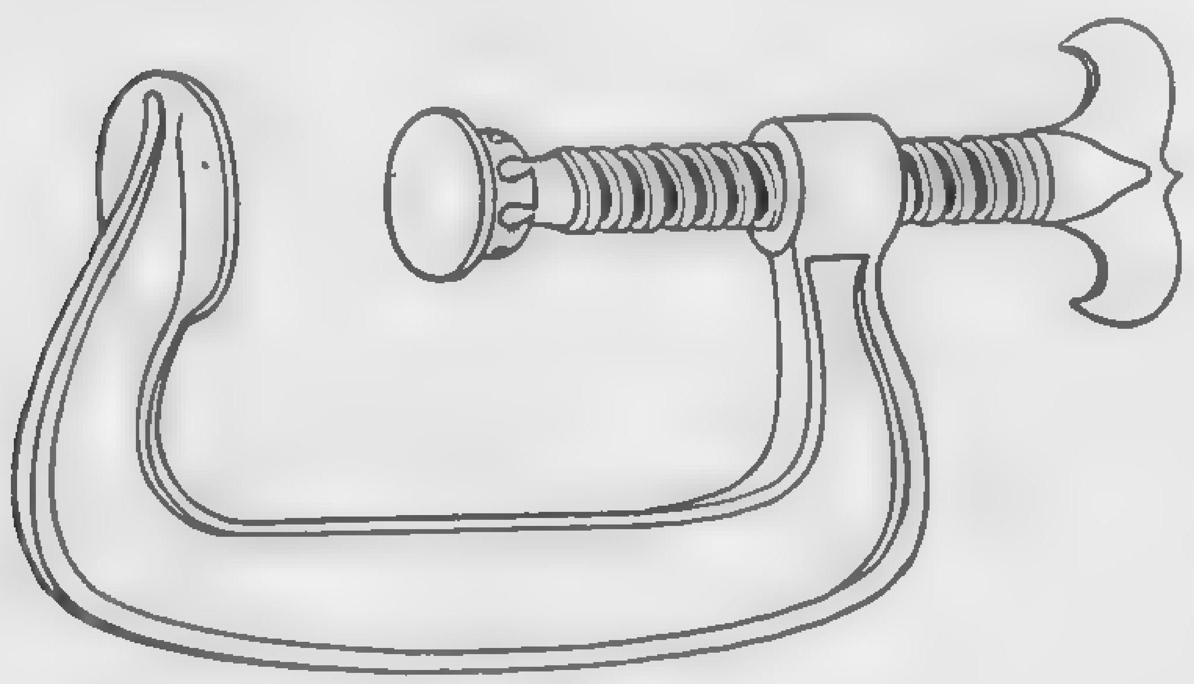


Fig. 75. Iron Clamp

**Abrading Tools.** *Wood Files.* The half-round cabinet file and half-round cabinet rasp, shown in Fig. 76, enter largely into the work of the pattern maker, and should be bought in sizes each of 6 inches, 8 inches, and 10 inches. Larger as well as intermediate sizes may often be found necessary, but will not be needed for ordinary work.

*Oil Stones and Slips.* As before stated, new planes, chisels, and other edged tools, if of the best quality, are always sold ground and sharpened, ready for use. When used, however, they soon become dulled, and must then be resharpened, and be so kept as to have a smooth keen cutting edge in order to do good work and to work rapidly. The method employed for doing this is the same for all edged tools, whether ground and sharpened on one side or on both sides.

Oil stones are used for plane irons, chisels, and all flat and straightedged tools; and oil slips, having rounded edges, are used for gouges, and for all tools having curved edges. They are made of different sizes, and may be found of many and widely different qualities. The best known and most widely used oil stones in this country, and perhaps in the world, are the Washita, of which the Lily White Washita brand, being carefully selected, is the most



even in grade and quality, and is the best-adapted natural stone for woodworkers' tools. For wood-turners' and pattern-makers' tools, the sharpening qualities of the Washita are unsurpassed; but the quality differs greatly in stones sold under this name, some being uneven in hardness, and some soft and worthless. No trouble will be found, however, if some well selected brand such as the one mentioned above is chosen.

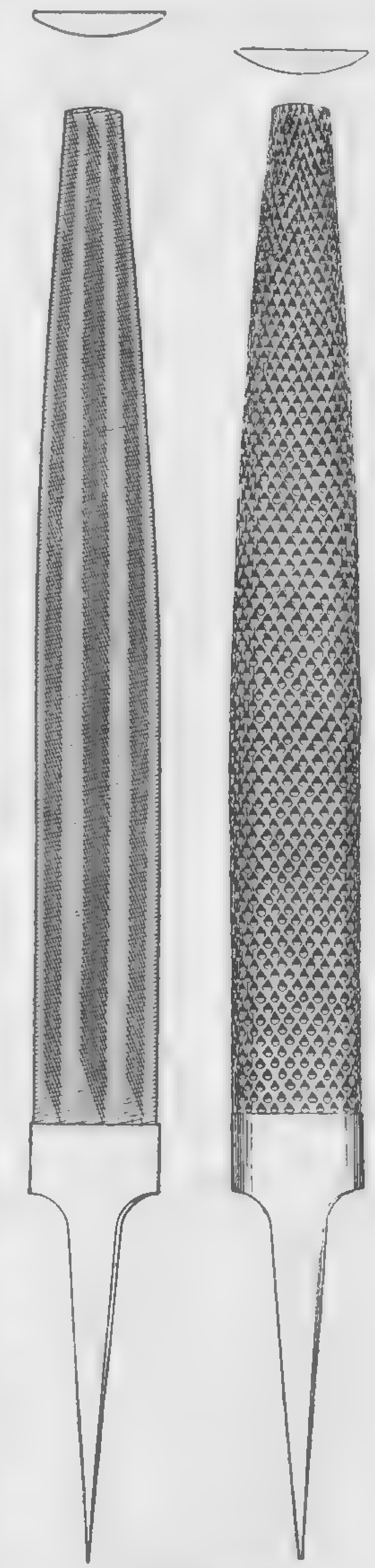


Fig. 76. Cabinet File and Rasp

The Arkansas oil stones are claimed to be the hardest and finest oil stones in the world. They are composed of nearly pure silica in the form of minute crystals interpenetrating one another, and differ from the Washita only in the minuteness of the crystals and in their more compact arrangement. They are consequently very much harder, and cut hardened steel more slowly than coarser grades of stone, but impart a finer and smoother edge to the tool. They are used by wood carvers, engravers, watchmakers, and others using tools that require a very fine edge or point. They are expensive, and should be used carefully with equal parts of sperm oil and glycerine.

A good size for an oil stone is 6 inches to 8 inches in length, and from $1\frac{5}{8}$ inches to 2 inches in width. The thickness does not matter, but the stones usually vary from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches in thickness. The oil slip should be about $4\frac{1}{2}$ inches in length, and from $1\frac{3}{4}$ inches to 2 inches in width, tapering from $\frac{5}{8}$ inch on one edge to $\frac{3}{16}$ inch on the other, both edges being rounded as shown in Fig. 77.

In using the oil stone, care should be taken to hold the bevel of the tool flat, or nearly flat, on the stone, so that the cutting edge may

be kept thin and in easy working condition. The stone is held stationary on the work bench, and the tool is moved forward and backward over its face. In the use of the oil slip, on the other hand,

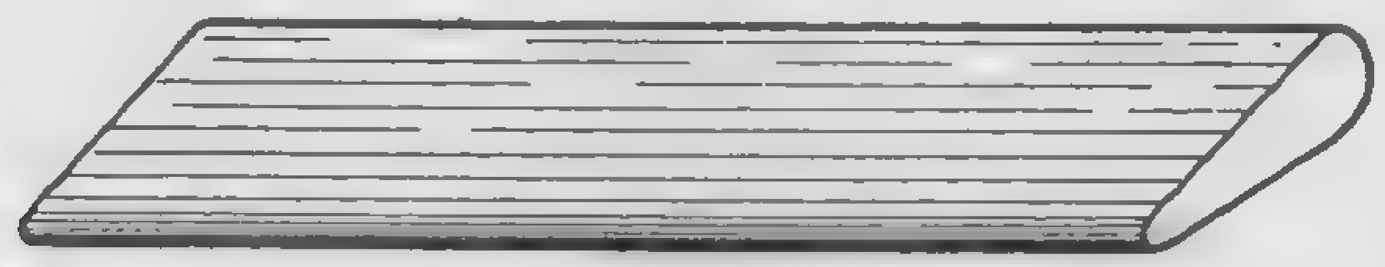


Fig. 77. Oil Slip

the tool is held stationary, with the cutting edge or end up, and the slip is rubbed over the beveled surface with a circular motion or stroke, until a keen sharp edge has again been imparted to it. An abundance of oil should always be used in order that a finer and smoother edge may be given to the tool, and the pores of the stone be kept clean and free from glazing.

A number of years ago an entirely new variety of oil stone and oil slip was placed on the market. It is called the India oil stone, and is made from corundum, the hardest of all mineral substances except the diamond. These stones have wonderful cutting qualities, and differ greatly from other oil stones in that they cut steel much faster, impart better edges, and do not glaze. They are also of uniform texture throughout. India oil stones are furnished in three grades—coarse, medium, and fine—and in all required shapes, a few of which are shown in Fig. 78. Only the fine stones are adapted for woodworking tools and for those classes of tools requiring a fine cutting edge.

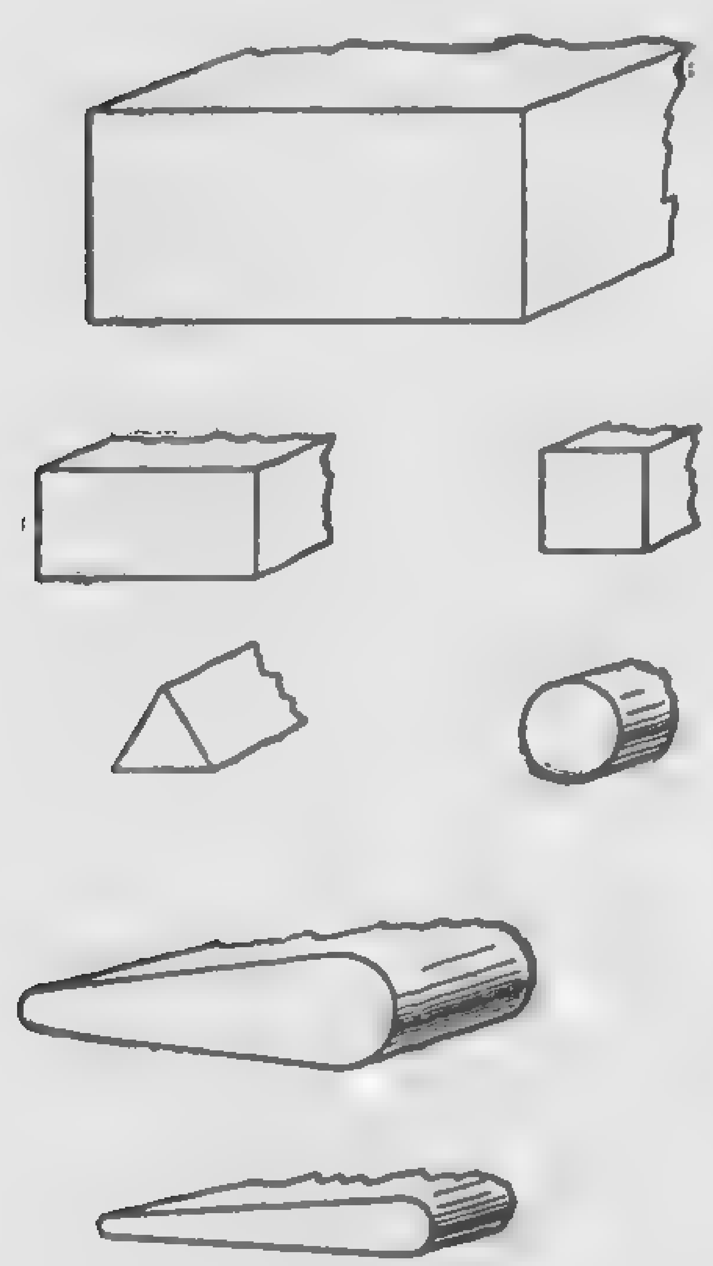


Fig. 78. Shapes of Oil Stones

*Grindstones.* Second in importance to a good oil stone is the grindstone, power driven if possible. It should not be too close-grained. A rapid cutting stone, even if moderately coarse, is greatly to be preferred, as all ground edges must be finally finished on the oil stone however finely they may have been ground on the grindstone. A stone about 36 inches in diameter when new,





is a good size, and can be bought with a suitable cast-iron trough underneath, and also with an arrangement for supplying the water necessary to keep the stone wet.

In all stones there will be found great differences of hardness in different parts. Stones soon lose their cylindrical shape and must be turned true. A piece of gas pipe or an old file will be found excellent tools for this purpose, but they must be used without water.

In using the grindstone for plane irons, chisels, and other tools that must be ground with a long bevel or to a thin edge, it is better to stand so that the stone runs toward the cutting edge of the tool, as shown in Fig. 79. This position grinds the tool much faster, and less of a feather will be turned up on the final edge. Scraping tools, however, and indeed all tools having a very short bevel, or whose edges are ground to a very obtuse angle, may be held so that the stone will revolve away from the cutting edge of the tool, this position being less liable to cut hollows in the face of the stone. This method of grinding, however, is too slow for tools having a long bevel, and which for that reason require more grinding.

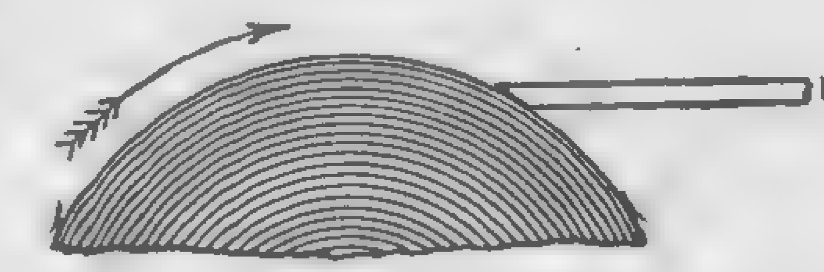


Fig. 79. Grinding Long Bevel

When to use the grindstone is a question that often occurs to the beginner, who sometimes confuses the use of the grindstone with that of the oil stone. The grindstone is not in any sense an instrument for sharpening woodworkers' tools. When a chisel or a plane iron has been sharpened on the oil stone for several successive times, the bevel is gradually worn shorter, and its shape changed from that shown at *a*, Fig. 80, to a shape similar to that shown at *b*. When the length of the bevel is thus reduced, the angle of the cutting edge is too obtuse to do good work or to work easily. The metal at *c* must then be ground off on the grindstone, and the bevel of the tool restored to its former correct shape, as shown at *a*, after which the cutting edge must be sharpened and finished on the oil stone.


Fig. 80. Sharp and Worn Bevels

## MACHINE TOOLS

**Lathe Equipment.** Of all power-driven machines, the most indispensable to woodworkers is the wood-turning lathe, Fig. 81.

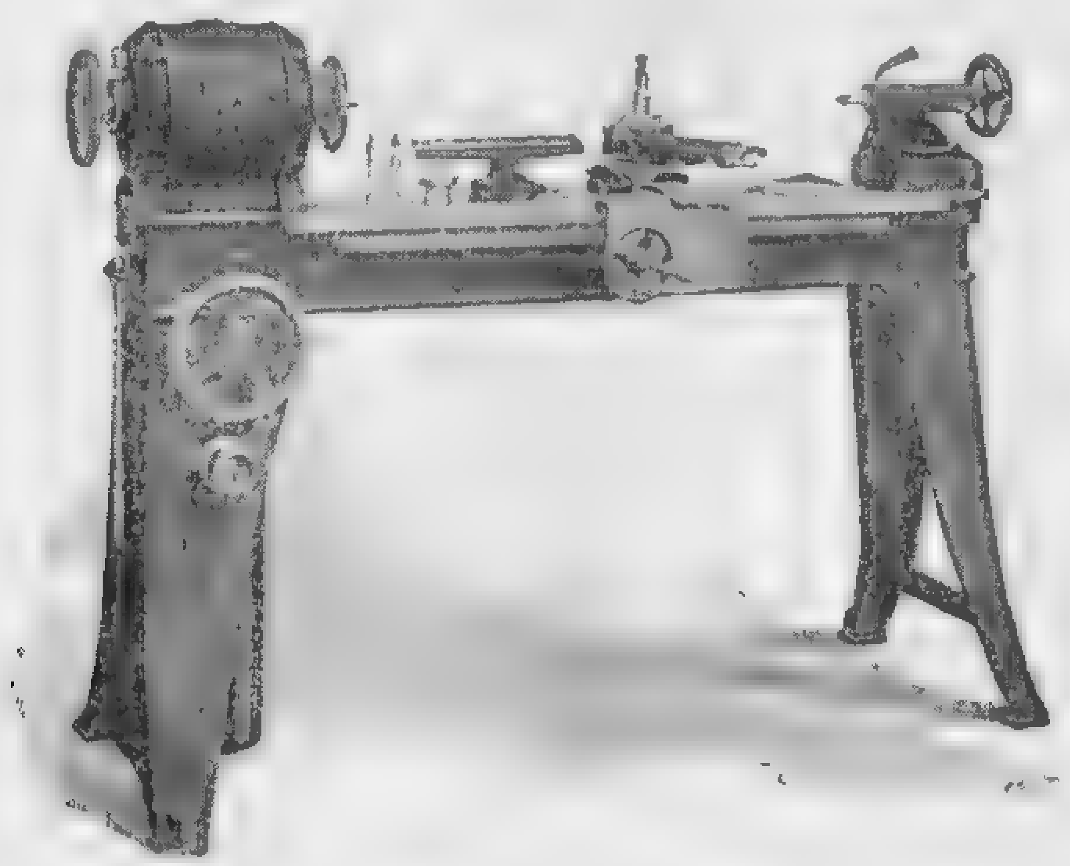


Fig. 81. Woodworker's Speed Lathe
*Courtesy of Oliver Machinery Company, Grand Rapids, Michigan*

Lathes may be driven by belts from countershafts or be driven by individual motors mounted directly on the lathe. Speed variations may be had by shifting the belts on cone pulleys or by varying the speed of the motor itself.

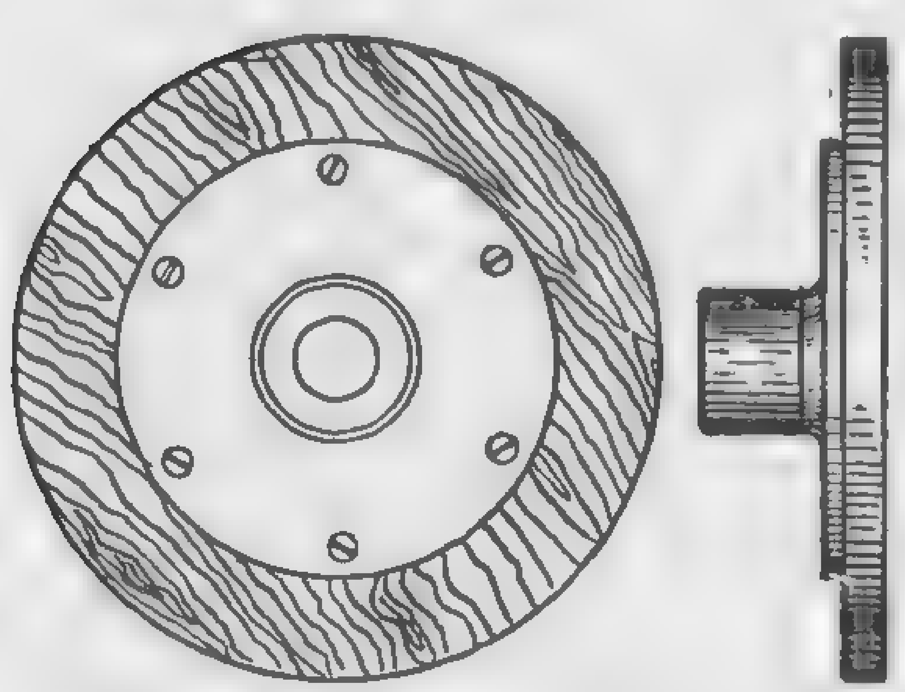


Fig. 82. Construction of Small Faceplate

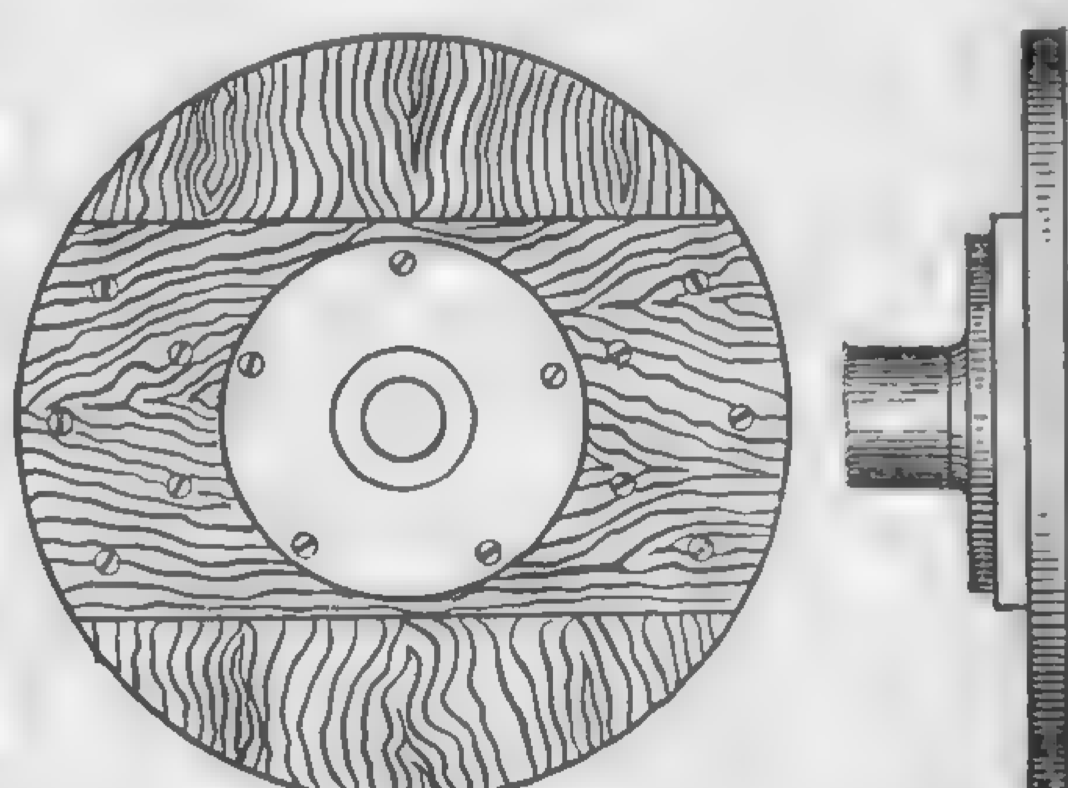


Fig. 83. Medium-Sized Faceplate Construction

*Faceplates.* A variety of chucks and faceplates for holding the work is always furnished with a lathe. In addition to these faceplates, which really form the base only for mounting the work, wooden faceplates (see Figs. 82 and 83) must be used between the iron faceplate and the work.





*Turning Gouge.* Of lathe hand tools the first to be considered, as also the first to be used, is the gouge. It is used for reducing the stock to be turned, from a rough or rectangular shape to a cylindrical

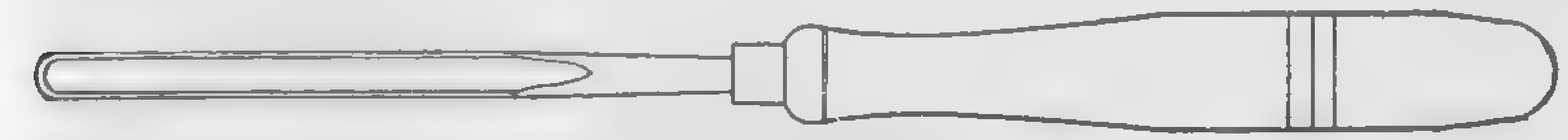


Fig. 84. Turning Gouge

form, preparatory to smoothing and finishing. It is ground and beveled on the back or convex side, and the shape of the cutting edge should be of the same curvature as the inside, or upper side, of the tool. Gouges are made in all sizes, one of which is illustrated in Fig. 84; but for ordinary turning use four gouges, ranging from ¼ inch to 1¼ inches, will be found sufficient for all purposes.

Before using the gouge, and indeed any lathe cutting tool, the workman should take care to see that the tool rest has been elevated above the center line of the lathe centers, from ¼ inch for small work, to 1 inch or more for large work. The position of the gouge, when in use, is horizontal and at about a right angle to the tool rest. It should not, however, be laid on the rest so as to use only the extreme point of the tool, but should be tilted over, first to one side and then to the other, so as to bring all parts of the cutting edge, successively, in contact with the wood that is being turned.

The gouge may be used by the beginner without hesitation, as in no position, whether tilted or on its back, will it catch or rip into the wood. The tool should be held firmly by the extreme end of the handle, in the right hand, while the left hand rests against the tool rest, the blade of the tool being grasped lightly with the fingers, and passing through and under the left hand while resting on the tool rest.

*Skew Chisel.* As the turning gouge—being curved—can be used only as a roughing-down tool or for turning out hollows, and cannot

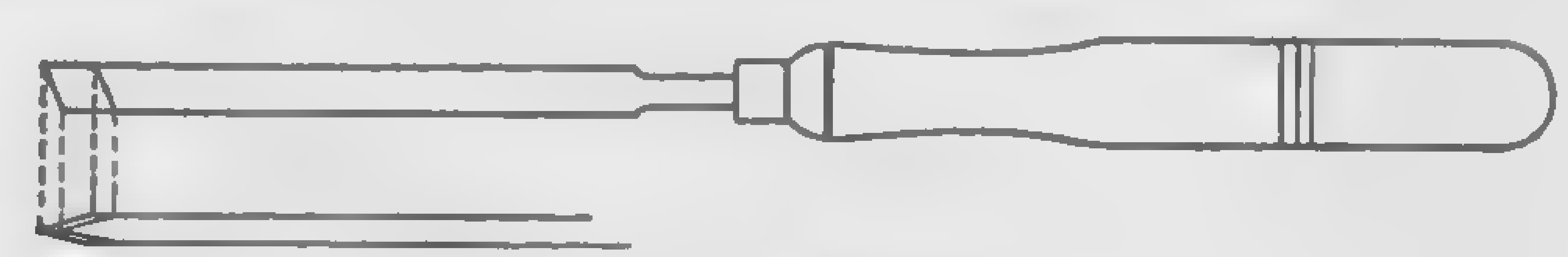


Fig. 85. Skew Chisel

be used for finishing, the skew chisel, one size of which is shown in Fig. 85, is used, in common and ornamental turning to make a

straight, true, or smooth surface. This form of chisel is made in all sizes from $\frac{1}{8}$ inch to $2\frac{1}{2}$ inches in width, but, unlike the gouge, requires considerable practice and skill for its successful use.

The skew chisel is held slightly tilted in order that while the short edge of the blade touches the tool rest, the long edge will be slightly above the rest, so that the long corner of the skew point extends up and well over the cylinder which is being smoothed, thus preventing the long skew point from catching and tearing into the work. All the cutting must be done with the short part of the skew edge, say $\frac{1}{2}$ inch only of the cutting edge, the tool resting not only on the tool rest, but resting also firmly on the cylinder that is being turned, just as a plane rests on a board while cutting and removing the shavings from its surface. The right position for this

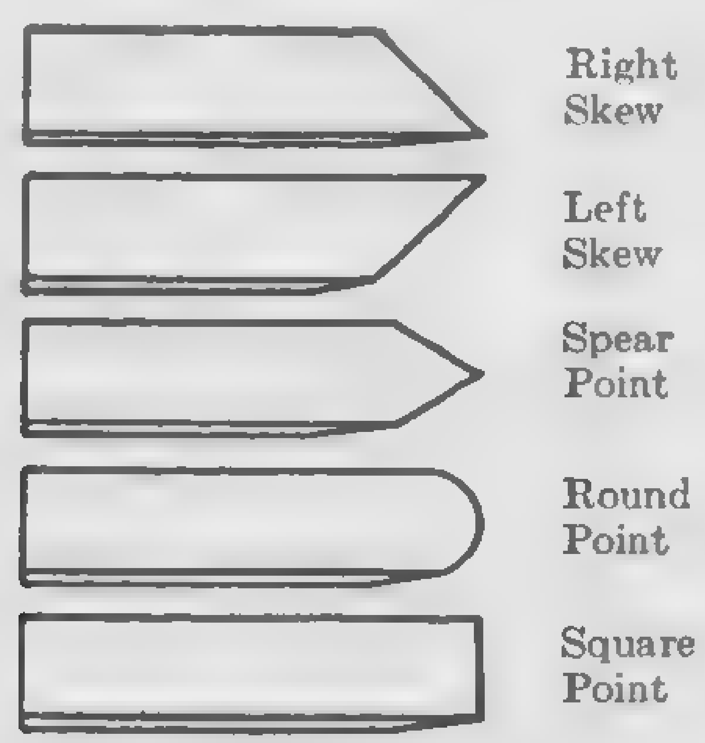



Fig. 86. Scraping Tools

tool is hard to obtain at first, and can be acquired only by patient and continued practice. In no case, however, should the skew chisel be held flat on the tool rest, or used as a scraper, this not being allowable or good practice either in common or in ornamental turning. One skew chisel each of the $\frac{1}{4}$-inch, $\frac{1}{2}$-inch, 1-inch, and $1\frac{1}{2}$-inch sizes will be found sufficient for all ordinary work.

*Scraping Tools.* While the skew chisel works with great rapidity and does smooth and very satisfactory work in all kinds of ornamental turning, the dimensions obtained with this tool are not so accurate as those obtained by the scraping tools.

Scraping tools are made in many forms and shapes, and are ground by the workman to suit the requirements of his work. A few of the many shapes in common use are illustrated in Fig. 86.

These tools should be ground with a very short bevel, and





must be sharpened much oftener than a cutting tool for the revolving wood, passing at right angles to the sharp edge, wears it away more quickly than it can a cutting tool.

*Cutting-Off Tool.* A very necessary tool for all kinds of wood turning is the parting or cutting-off tool, shown in Fig. 87. This is

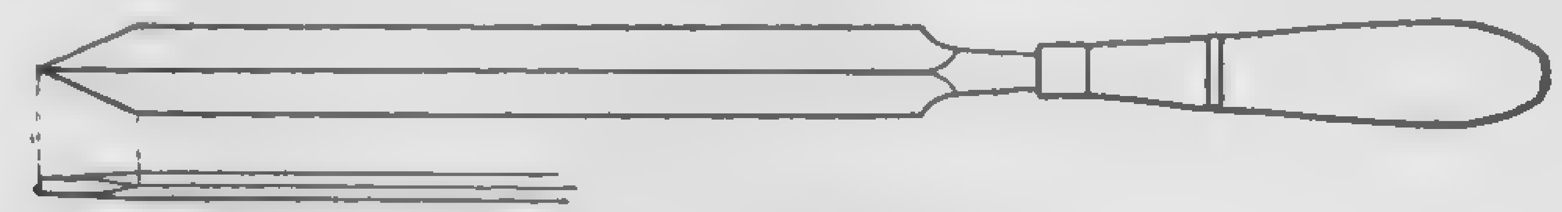


Fig. 87. Cutting-Off Tool

used as a scraping tool for cutting recesses in the work and for cutting off finished work from the faceplate, and will also be found useful for many other purposes.

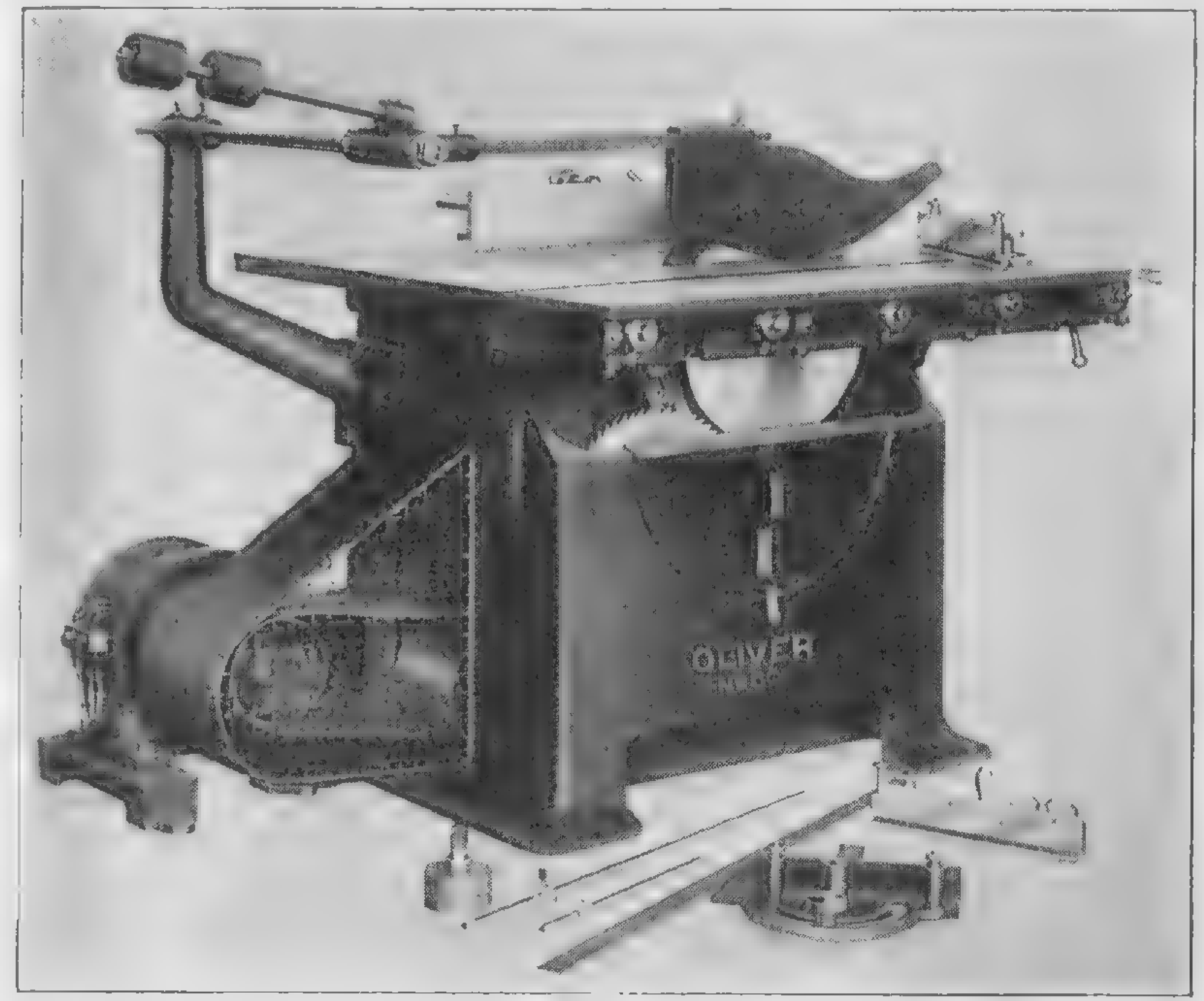



Fig. 88. Universal Saw Bench with Self-Contained Motor Drive
*Courtesy of Oliver Machinery Company, Grand Rapids, Michigan*

**Sawing Machines.** *Circular Saw.* As a time-saving and labor-saving machine a good circular-saw bench is necessary in every well-equipped woodworking shop, and is unsurpassed in capacity and in the variety of work for which it may be used. As shown in Fig. 88,

it is permanently provided with two saw arbors one carrying a rip saw and the other a crosscut saw, either of which may be raised

Fig. 89. Saw Table Tilted to 45 Degrees with Universal Ripping Fence
*Courtesy of Oliver Machinery Company, Grand Rapids, Michigan*

easily and quickly to cutting position, the other being depressed at the same time. The front half of the table is made to slide, while the whole-table can be tilted to an angle of 45 degrees, as shown in

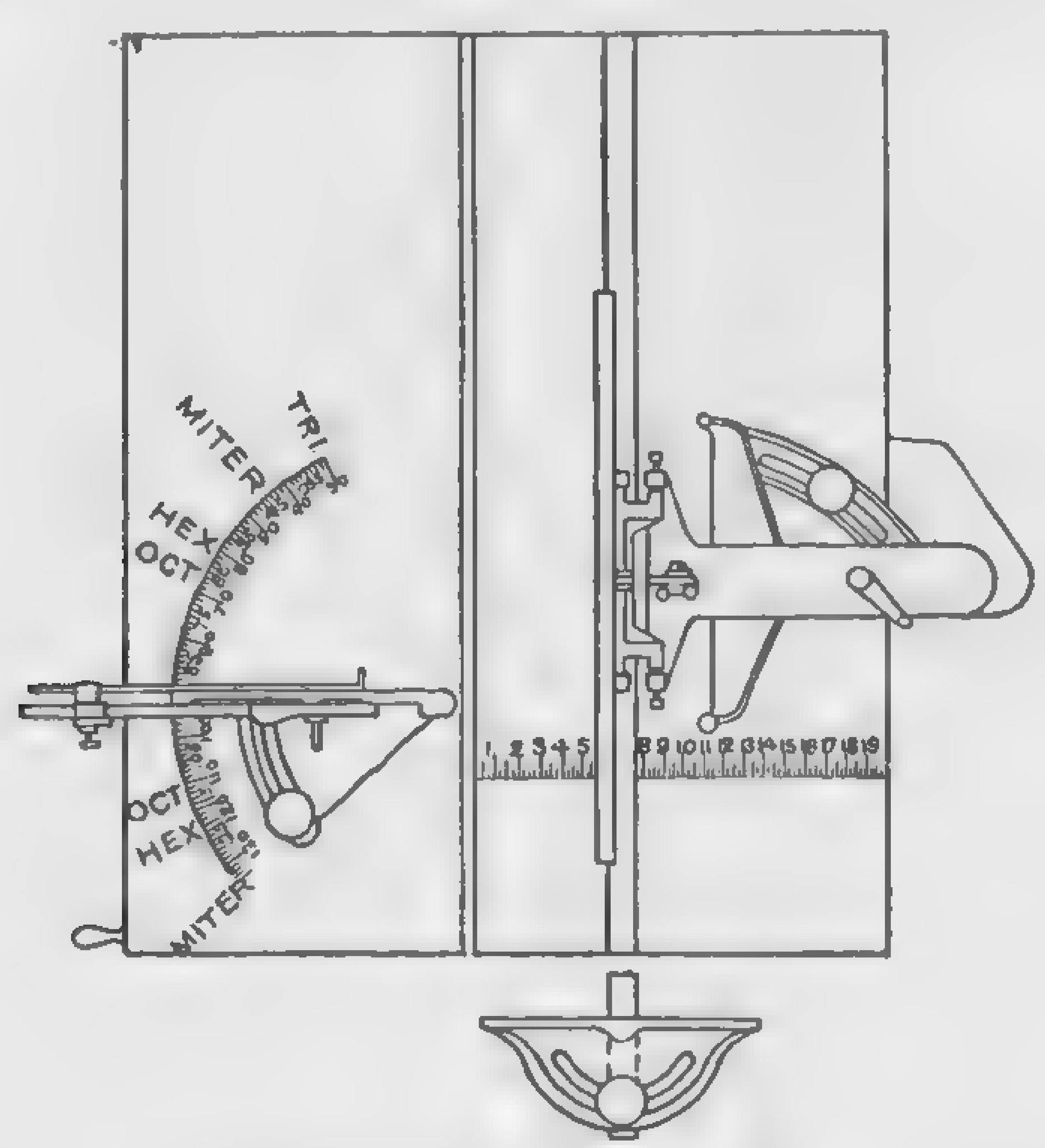



Fig. 90. Plan of Saw Table

Fig. 89, and will remain in any position desired without clamping. As shown, it is provided with adjustable gages for cross-cutting or mitering, and with an adjustable fence for ripping, all of which





are removable at will, leaving the whole upper surface of the table clear. Fig. 90 gives a view of the table from above. As in the case of the turning lathe, the intended speed of the saw countershaft is indicated by the manufacturer.

The single-arbor circular-saw bench is a less expensive machine than that just described; but the time lost in having continually to change the saw on the single arbor from rip to crosscut and back again for changes in the work is a very annoying as well as expensive inconvenience.

*Band Saw.* A good band saw, such as the one illustrated in Fig. 91, is indispensable for cutting the curves and irregular shapes.

Fig. 91. Band Saw with Tilting Table
*Courtesy of Oliver Machinery Company*
*Grand Rapids, Michigan*

The best machines of this description have a tilting table which can be set and clamped at any angle, enabling the workman to give the required bevel or draft to his work.

**Trimmers.** Among the many labor-saving tools of late years, there is the universal wood trimmer. It will cut any end or angle within the capacity of the machine; and an end which would take from 10 to 15 minutes to square and true up correctly by hand, with square and plane or chisel, can be finished in as many seconds

with this tool. It is made in many sizes, from the small bench trimmer shown in Fig. 92, to a large universal machine mounted on its own base.

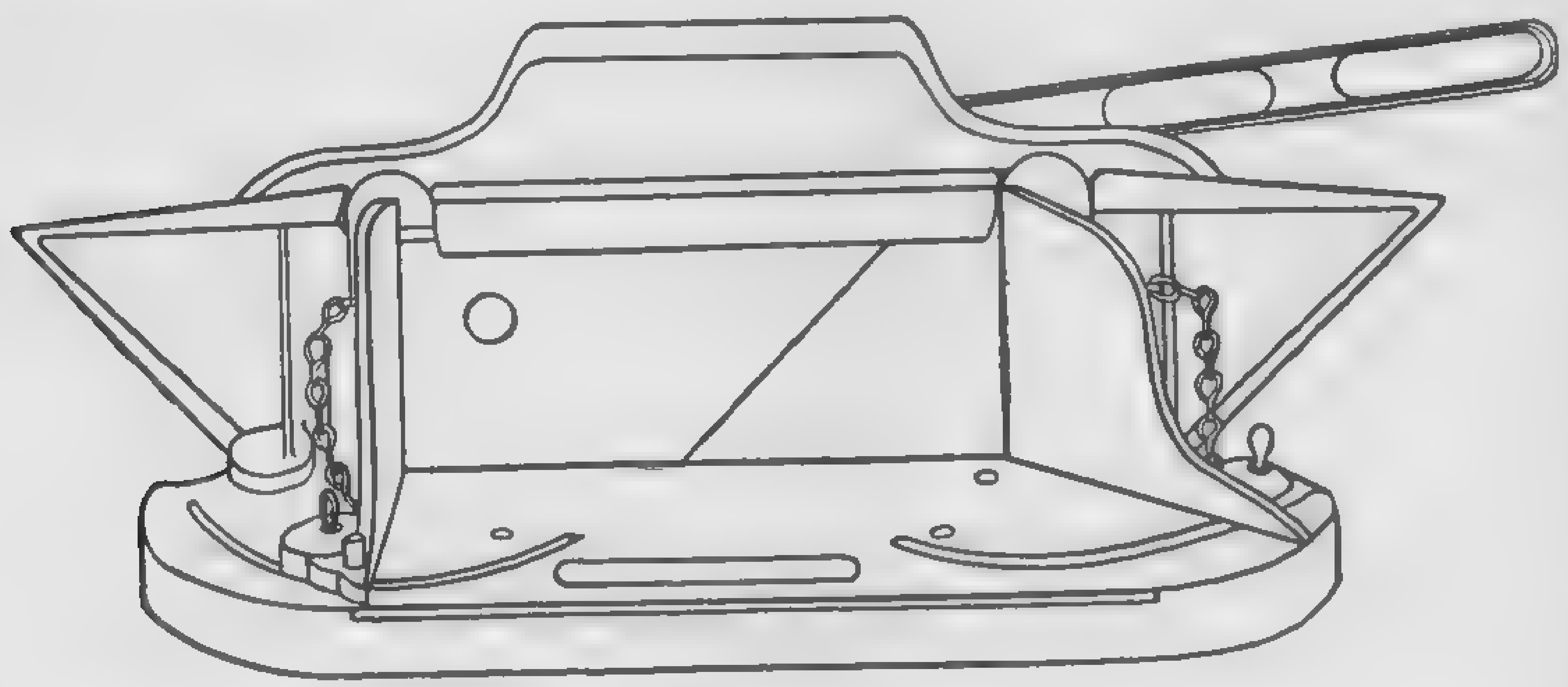


Fig. 92. Bench Trimmer

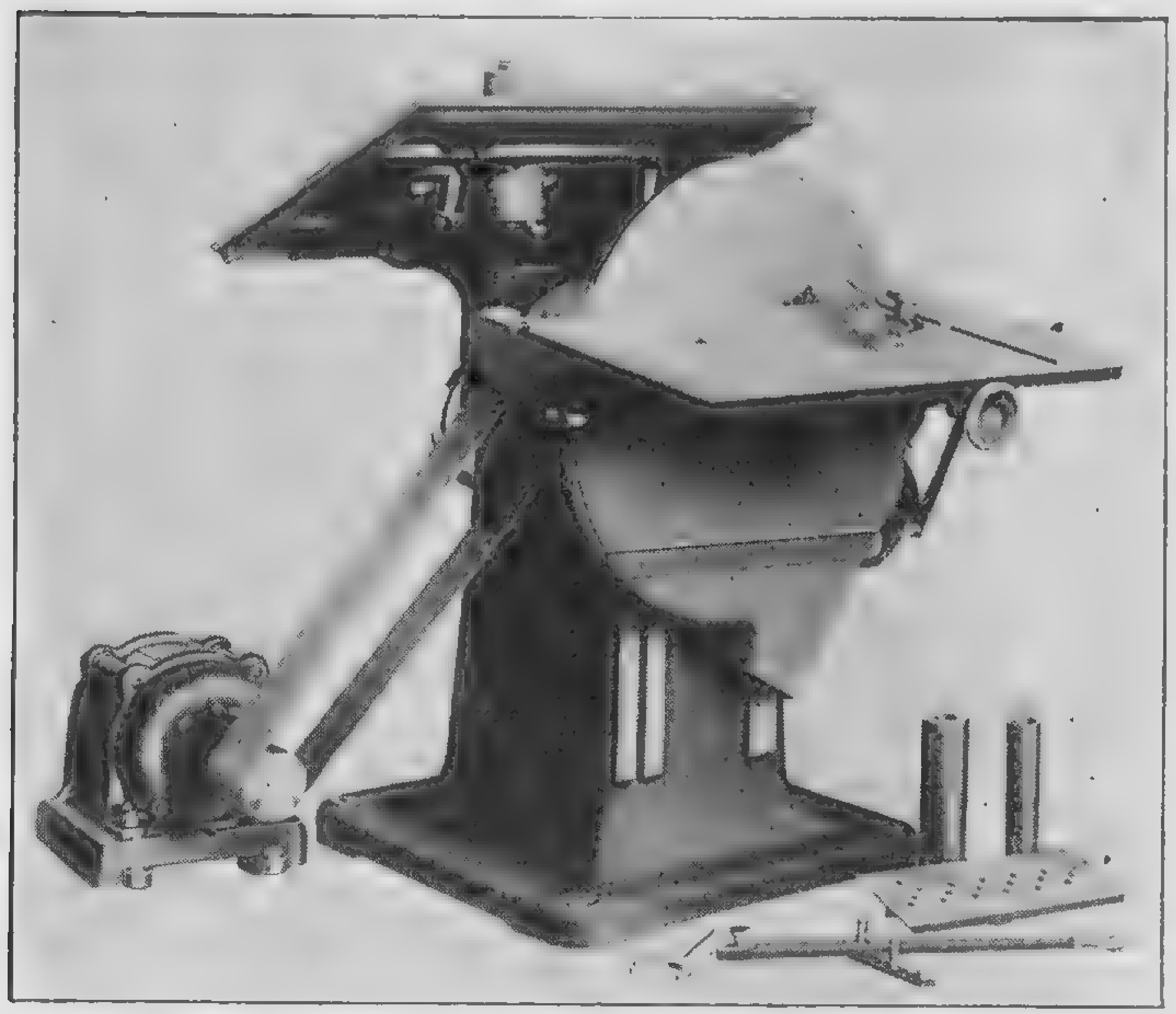


Fig. 93. Combination Vertical Spindle and Disk Sander
*Courtesy of Oliver Machinery Company, Grand Rapids, Michigan*

**Sanders.** Grinding has become as important a method of shaping wood as of metal as is evidenced by the numerous types of sanding machines that have been developed. Two of these, the vertical spindle sander and the disk sander, are of primary importance in the pattern shop. In general they are wood-working machines, but they may be used for finishing metal patterns as well.





The combination vertical spindle and disk sander shown in Fig. 93 is designed especially for sanding irregular shapes.

## WOOD FASTENERS, JOINTS, AND FINISHING

Figs. 94 and 95 illustrate the use of a claw hammer in driving and pulling nails.

**Nails.** In general, nails are of two kinds; namely, cut nails and wire nails, the difference between the two kinds being in the material and the method of manufacture. See Figs. 96 and 97.

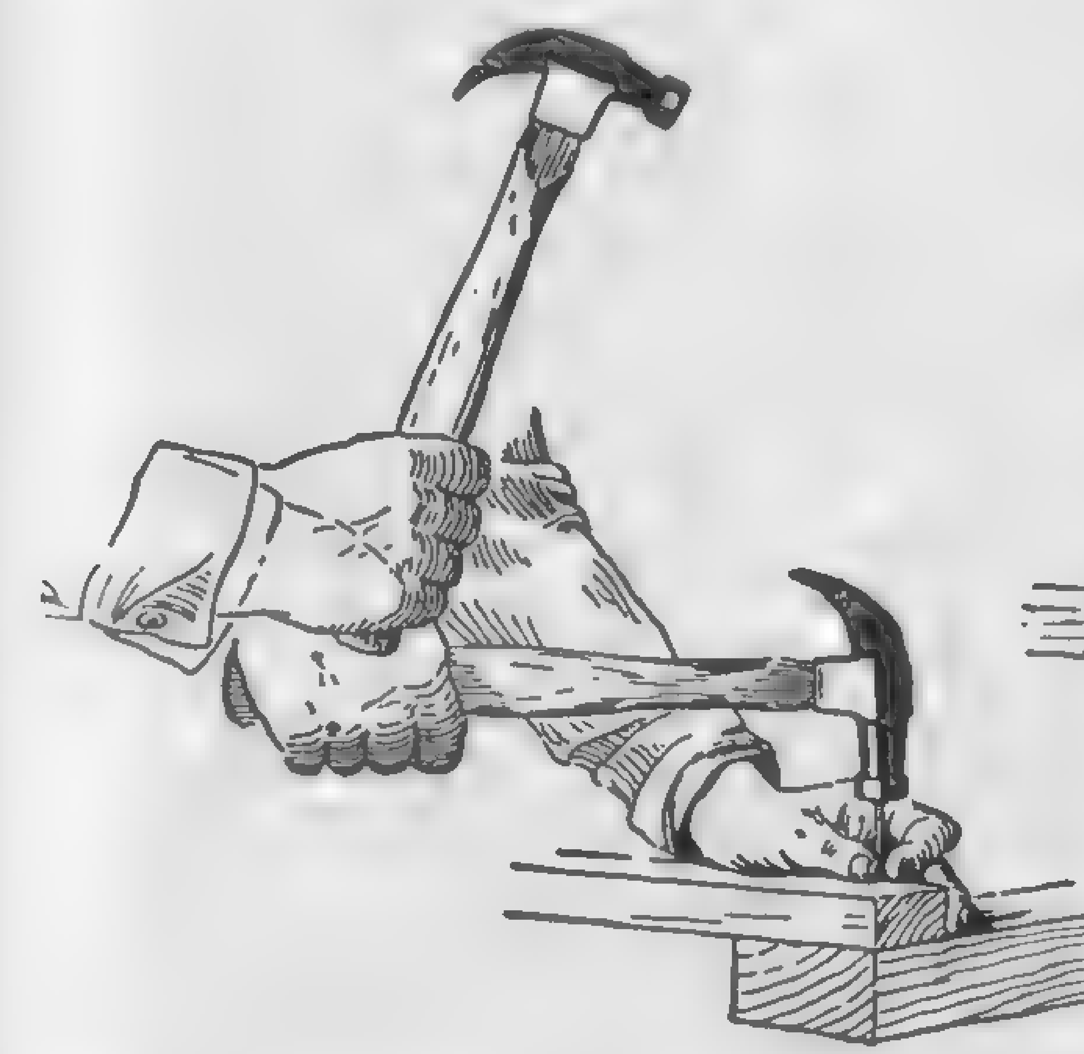


Fig. 94. Showing How to Drive a Nail

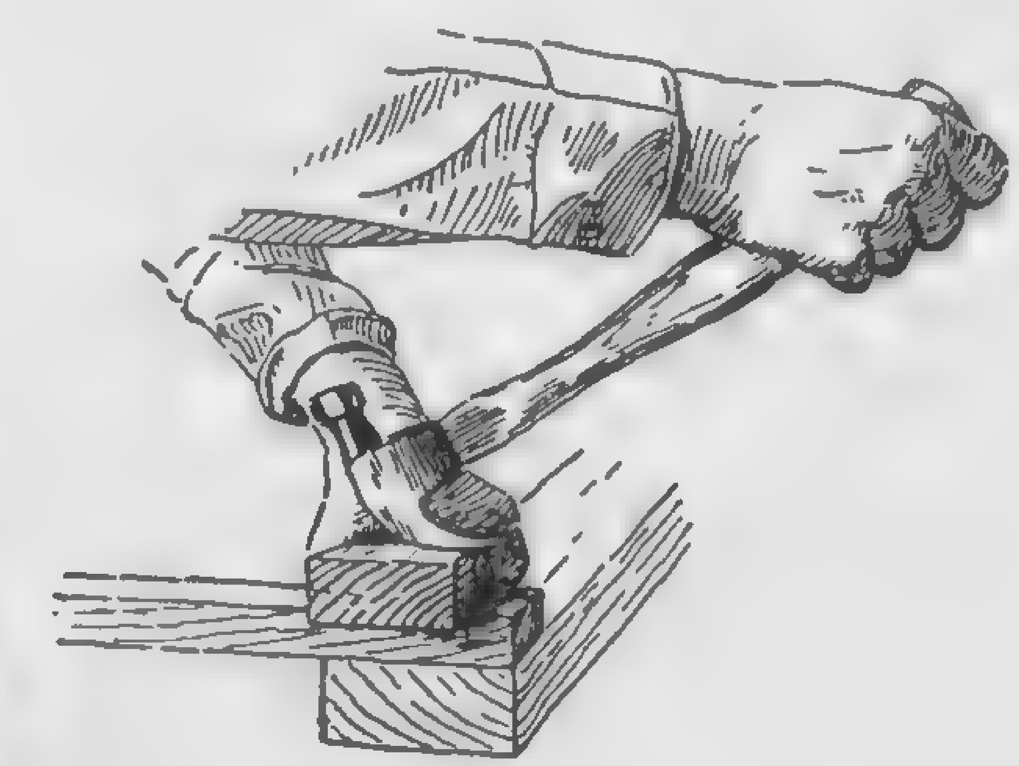


Fig. 95. Pulling a Nail. The Block of Wood Under the Head Increases Leverage

*Cut Nails.* These nails, also formerly called plate nails, used to be stamped out of a flat iron plate, in alternate, slightly wedge-shaped pieces, and the head afterward formed on the large end of each piece. The cut nails are now made in much the same shape as the old iron nails, but are cut from steel plate by a machine which also forms the head. They come in three classes, according to finish, and are called, respectively, "common," "casing," and "finish" nails. The nails known as "finishing nails," however, are far too rough for fine finished work. The length of the nail is regulated according to the "penny," which formerly had reference

to the weight, but which now is purely arbitrary. Thus a three penny nail is $1\frac{1}{4}$ inches long; four penny, $1\frac{1}{2}$ inches; five penny, $1\frac{3}{4}$ inches; six penny, 2 inches; seven penny, $2\frac{1}{4}$ inches; eight penny, $2\frac{1}{2}$ inches; nine penny, $2\frac{3}{4}$ inches; ten penny, 3 inches;

Fig. 96. Standard Common Cut Nails
Cut, Casing and Flooring Nails

twelve penny, $3\frac{1}{4}$ inches; sixteen penny, $3\frac{1}{2}$ inches; twenty penny, 4 inches; thirty penny, $4\frac{1}{2}$ inches; forty penny, 5 inches; fifty penny, $5\frac{1}{2}$ inches; and sixty penny, 6 inches. The specifications which have just been given for cut nails also hold good for wire nails.

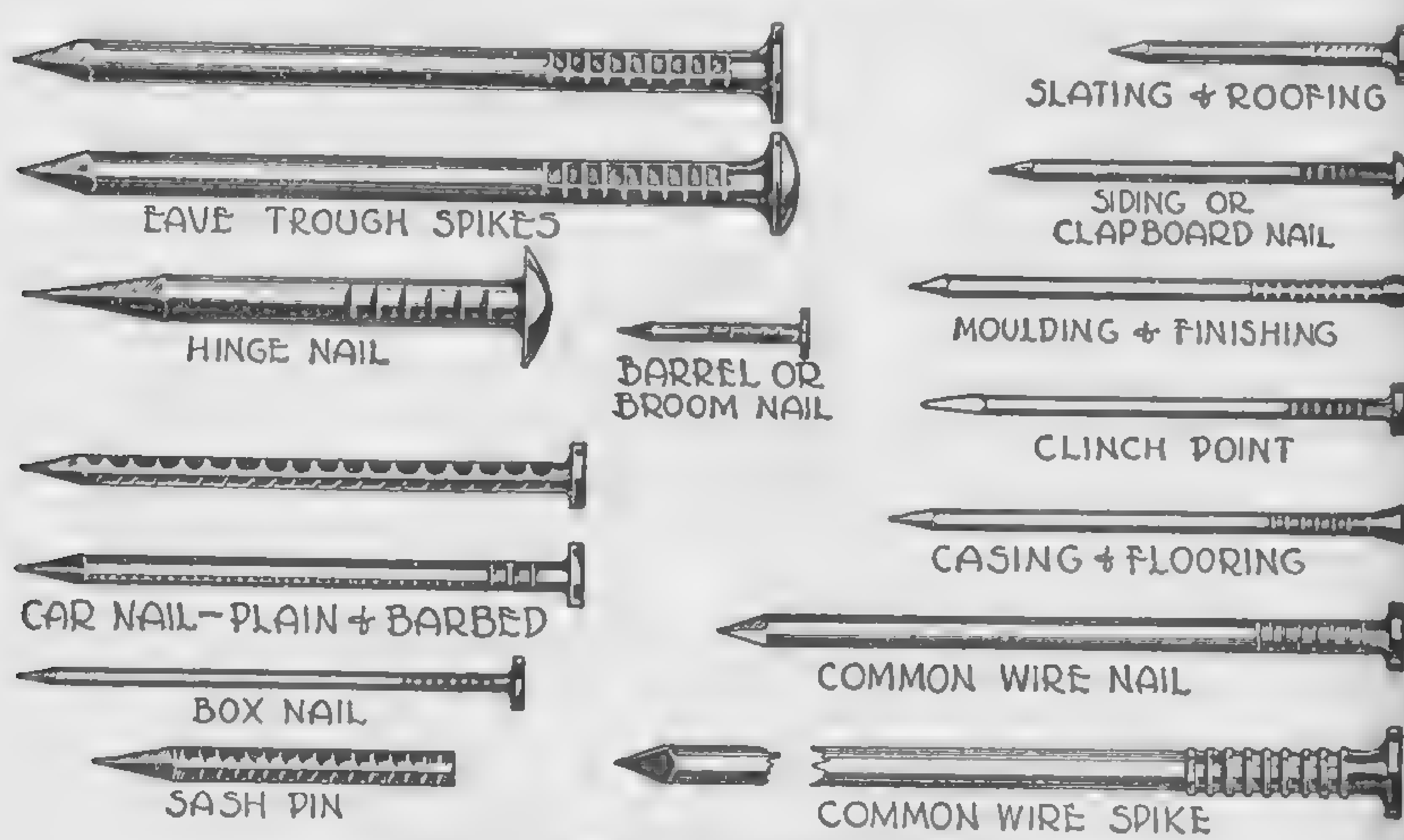



Fig. 97. Standard Steel Wire Nails

*Wire Nails.* Wire nails are rapidly replacing the cut nails in general use. They are now very nearly the same price and are very much stronger, so that they do not buckle up when driven into hard wood, and they are not nearly so liable to split the wood on account of their cylinder-shaped shaft, which is the same size





throughout its entire length. They are made from wire, which is cut in lengths by machinery and pointed and headed. They can also be ribbed or barbed, if desired, which gives them a stronger hold on the wood. They are made with various kinds of heads, some being large and flat, so that the nail can be easily withdrawn, while others are very slightly larger than the shaft of the nail and can be made almost invisible in the finished work.

For framing, large nails should be used, from 4 to 6 inches in length. For the rougher exterior and interior finish, such as sheathing and rough flooring, nails about 3 inches long are suitable, while for the finer inside finish smaller nails from $2\frac{1}{2}$ inches down to $1\frac{1}{2}$ inches should be used. Roofing should be put on with special galvanized or copper nails so as not to rust out.

Both cut nails and wire nails are made with a special finish called "blueing" or with a coating of cement applied while the nail is hot, both of which processes are supposed to increase the holding power of the nail. They can also be had galvanized by an electric process or hot-dipped-galvanized. There is an extra charge for nails treated in any of these ways.

The value of nails in holding two pieces of lumber together and in resisting a force which may tend to pull the pieces apart has been found by carefully conducted tests at several Universities to be much greater with some kinds of wood than with others, and depending also upon whether the nails are driven into the wood parallel to the grain or across the grain. It has been found that with both kinds of nails the holding power is greater when the nail is driven into the wood across the grain than it is when driven parallel to the grain, but that this difference is much greater with cut nails than it is with wire nails. Moreover, wire nails when driven into hard dense wood, such as Southern Pine or Douglas Fir, hold nearly twice as well as the same kind of nail driven into soft wood, such as White Pine, and if driven into White Oak the nails would hold nearly three times as well as when driven into Southern Pine or Douglas Fir. With cut nails this difference in holding power in different kinds of wood is similar, but the difference is not nearly so great. Cut nails are harder to start pulling out than wire nails, but after they are fairly well started they pull out quite easily, so that on the whole, the wire nails seem to hold just about as well

as the cut nails. To properly hold a piece of lumber in place, the nails used should be of a length equal to three times the thickness of the lumber.

**Screws.** Screws are now used in building work to a much greater extent than was formerly the custom, largely on account of their decreased cost. They have the advantage over nails, as they do not split the wood, and they can be easily withdrawn when desired, without injuring the work materially. There are a great many different kinds of wood screws, which vary as to the shape of

Fig. 98. Types of Screws

the head, the size of the shaft, and the length. They are made in about the same lengths as those given above for nails, and with both round and flat heads. See Fig. 98.

Screws, however, are sold according to the length in inches and each length is made in a number of sizes, each size being designated by a number called the "gauge" of the screw, which corresponds to the diameter of the "shank" or the portion of the screw between the threads and the head. For instance, a No. 5 gauge screw is about $\frac{1}{8}$ inch in diameter and a No. 15 gauge about $\frac{1}{4}$ inch, a No. 34 gauge about $\frac{1}{2}$ inch, and so on. If you know what diameter screw you need and want to find the approximate gauge, subtract $\frac{1}{16}$ inch from the diameter and multiply by 80 and the result will be the





gauge. To find the approximate diameter from the gauge divide the gauge by 80 and then add $\frac{1}{16}$ inch.

Screws can be had in steel, copper, bronze and brass. They are also made with chromium or nickel or silver-plated finish to match finishing hardware. All screws are sold by the gross.

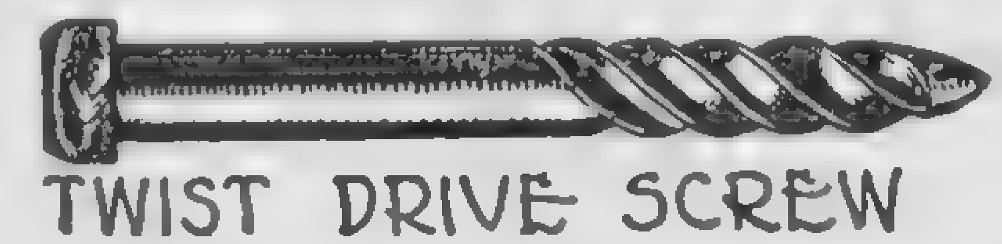



Fig. 99

If an ordinary screw is driven into the wood as one would drive a nail and is then screwed up tight with a screw driver, the fibers of the wood will be so badly crushed that the screw will not hold the pieces securely together. For this reason, one should always bore a hole in the wood before inserting the screw, the size of the hole being equal to the size of the threaded part of the screw without the threads. This is called the "core" of the screw. As the "shank" is larger in diameter than the core, it is necessary in hard wood to first bore a hole the size of the shank and as deep as the length of

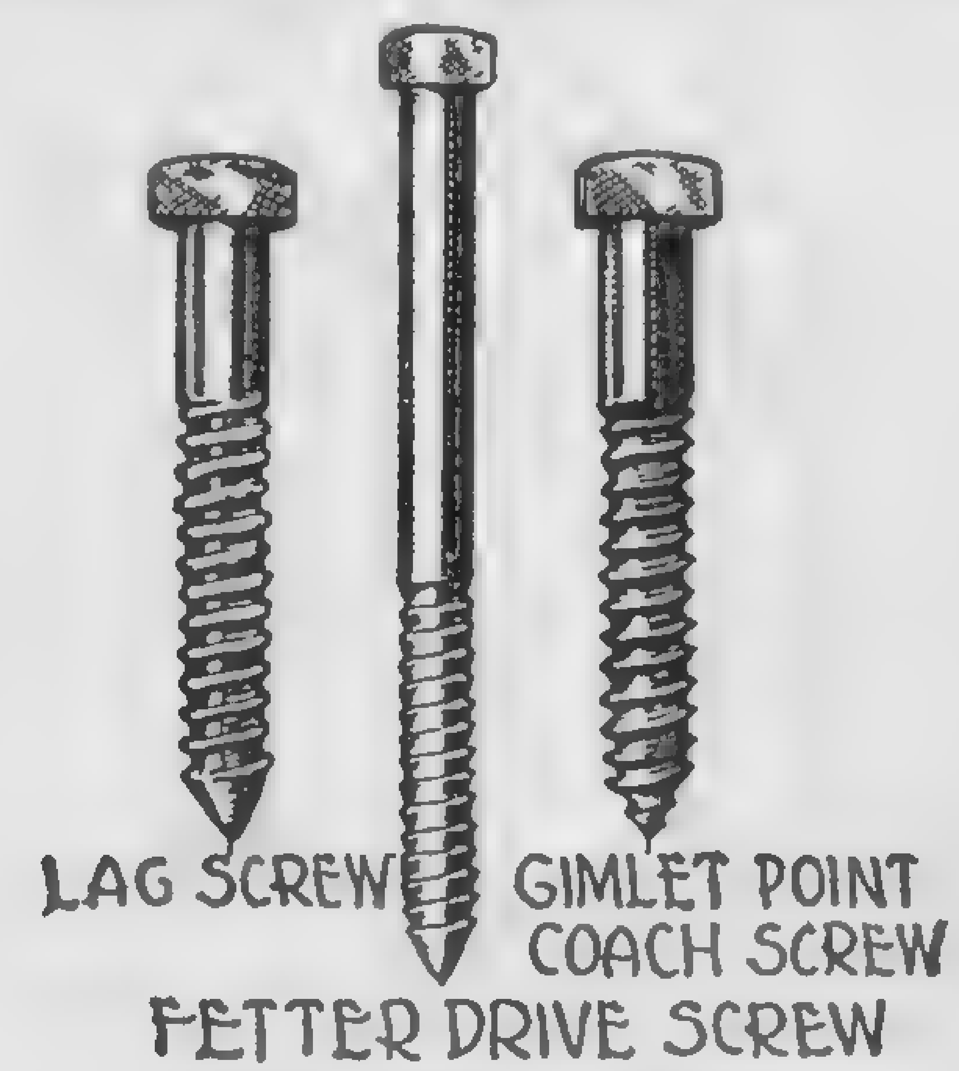



Fig. 100. Coach or Lag Screws

the shank and then take a smaller bit and continue the hole, making the deeper part equal to the diameter of the core. This is done so that the screw will not split the wood when it is driven home. There are special screws available which are so made that it is only necessary to bore one hole, even in hard wood, and other screws

called "drive screws" are made with the threads so far apart and so shaped that the screws can be driven with a hammer.

Tests have shown that the holding power of screws is more than twice as great as that of nails of similar size, but that "drive" screws are only about two-thirds as good as ordinary screws. These tests also showed that it made little difference whether the screws were driven into the wood parallel to the grain or across the grain, and that the holding power is in proportion to the size of the screw.

Screws are made with square heads for heavier work so that they can be driven home with a wrench instead of a screw driver. These are called "Lag Screws" when they have a "cone" point and "Coach Screws" when they have a "gimlet" point. They can be had in lengths from $1\frac{1}{2}$ inches up to 12 inches, and in diameters from $\frac{1}{4}$ inch to 1 inch. They are sold by the hundred and are designated by diameter and length in inches as "a $\frac{3}{8}$-inch lag screw 3 inches long." At a little extra cost, they can be had with heads hexagonal instead of square. In using lag or coach screws, it is necessary to first bore a hole the size and depth of the shank and then extend it with a smaller hole the size of the core. A square-headed drive screw is made which can be used without boring these holes, but its holding power is less. To make screws go in more easily, they may be treated with a heavy lubricant, such as tar soap, without any appreciable loss of strength. In hard wood it is often necessary to use a lubricant. Figs. 99 and 100 show several different kinds of screws.

**Wood Joints.** There are many kinds of joints used to fasten wood parts together, from the butt joint, which is simply placing the two pieces together at an angle and nailing or screwing them in place, to the blind dovetail which is used in the finest furniture construction. A few of the more common joints are illustrated in Fig. 101. Regardless of the type of joint used, the measurements must be accurate and the members cut square to insure a snug fit. A loose joint will weaken the entire structure.

**Preparation for Wood Finishing.** The plane usually leaves some small ridges or rough places on the surface of the wood. Before the work can be painted or stained, these must be removed. There are a great many elaborate methods used to prepare wood for finishing; only the simplest is described here.





*Sandpaper and Garnet Paper.* The scraper will not leave a surface very smooth, as it cuts at a fairly rapid rate and leaves some of the wood fibers turned up in the form of fuzz on the surface. An abrasive paper is used to cut this fuzz from the wood. *Sandpaper* consists of small particles of flint glued to a paper backing. *Garnet paper* is made in the same way except that the abrasive material cuts much better than flint and lasts longer.

Sandpaper is graded from 3/0 to number three, those grades in the zero series are considered fine, while those in the whole-

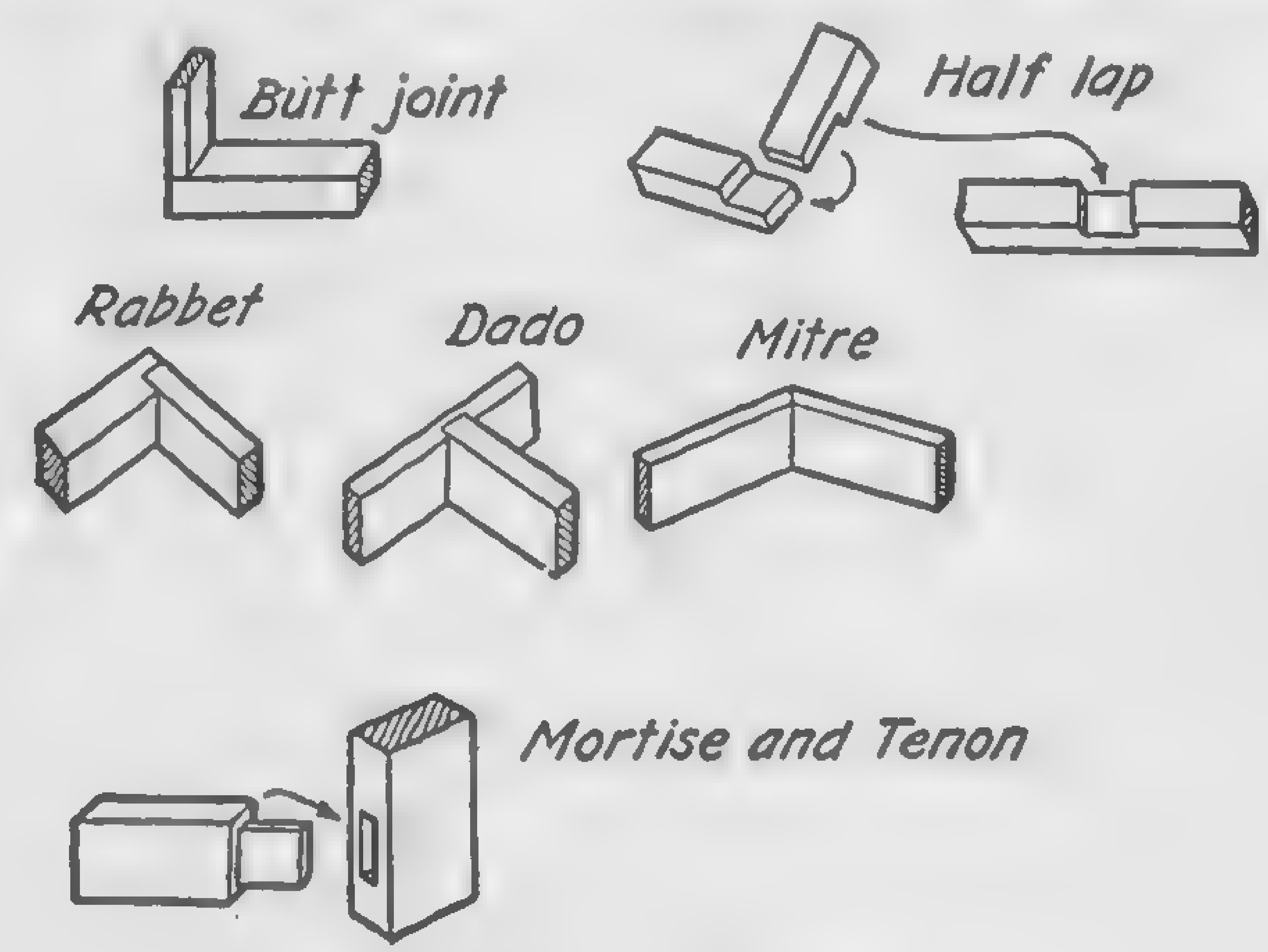



Fig. 101. Wood Joints

number series are considered coarse. Garnet paper is graded in the same way, except that the finest grade is 7/0.

A fairly coarse grade is used first and then the piece is finished with a fine grade. Always sand with the grain; sanding across the grain scores the wood, and this will show through a stained finish.

Sandpaper is also used to finish or polish some of the softer metals.

## SHOP KINKS

**Boring a Hole in Wood.** When boring a hole in wood, mark the center accurately by the intersection of two pencil lines. Make a small prick mark at the center to give the bit the correct starting point. When using an auger bit it is not necessary to press on the brace, as a thread in the spur of the bit will feed the bit into the wood. Test squareness by the use of a try-square before

boring very deep. If the hole is to be bored entirely through the wood, watch for the spur to come through on the opposite side, then stop boring. Reverse the job and bore from the other side. This will make a clean hole. If you bore right through without reversing, you will find that the wood will splinter on the lower side.

**Keeping Tools Sharp.** Both woodworking and metal-cutting tools show a thin bright line on the cutting edge when they are dull, and nothing is gained by continuing to use a tool in this condition. When sharpening a wood plane bit or a chisel, try to hold the tool steady while rubbing it on the oilstone; use a circular motion and cover as much of the stone as possible, as this helps to keep it true and free from hollows. Be sure to keep on rubbing the tool until a small burr appears on the cutting edge of the tool. Then turn the tool over, lay it flat on the oilstone, and rub off the burr. Be sure you do not tip the tool to any degree when carrying out this operation. If a wire edge appears on the tool, this can be taken off by running the edge across a piece of wood.

**Starting a Saw Cut.** When starting a cut with a saw, do not force the cutting action; let the saw ride lightly until the cut is started. In starting the cut, the saw can be guided by the aid of the thumb. Be sure that the thumb is not close to the wood, as there would be danger of cutting yourself. Cut as close to the line as possible. Check for squareness of your cut after starting it. Remember that the cutting is done on the downward stroke, but it must be a smooth stroke with power behind it.

When the cut binds the saw, this can be relieved by inserting a chisel or screw driver in the portion which has already been cut, thereby opening the kerf and relieving the pressure on the saw. A cut can be made with a backsaw in the same manner, remembering that in beginning the cut you must start with a light stroke and not force the saw. In the cutting stroke it is rather essential to follow through in a straight line; this makes for smooth operation of the saw and helps you keep close to the line of cut.

**Using a Screw Driver.** When driving wood screws, see that the end of the blade has parallel sides for the depth of the screw slot and that the tip is straight and square. Tips which are too wide,





tips which are too thin, too thick, or broken, will damage the screw slot and produce a botched job.

**To Prevent Rust on Tools.** When you have finished using a tool, wipe it off with an oily rag; this will prevent rusting. Remember that salt is present in perspiration and this, as well as moisture in the air, causes rust.

**Whittling.** When whittling with a knife, be sure to whittle with the grain. In whittling against the grain you find the shaving digging in deeper and it becomes difficult to control. Fine paring on the finishing strokes of a job can often be done best by holding the knife stationary, with the aid of the thumb, then pulling the job back against the blade of the knife. Very fine shavings can be taken by this method, and a better control can be had on the thickness of the shavings.

Keep the knife sharp; a dull knife, like a dull boy, isn't much good. In sharpening the knife on an oilstone, lay the blade flat on the stone, with the sharp edge toward you; then raise it just a little and pull the blade towards you in an oblique direction. See Fig. 102. When you come to the end of the stone, turn the blade over and push it away from you with the same kind of slanting stroke. In each case the cutting edge always meets the stone first, so that you are stroking against the cutting edge. This is the proper way to sharpen a knife. When the knife is thoroughly sharp, the edge will have a clean, dull appearance. If it is not sharp, a bright, shining line will be seen on the cutting edge. A finer edge can be had by stropping the knife on a piece of leather soaked with a little oil, fine emery, and crocus; or if these are not available a piece of leather belting, such as is used in driving machinery, makes a good strop.

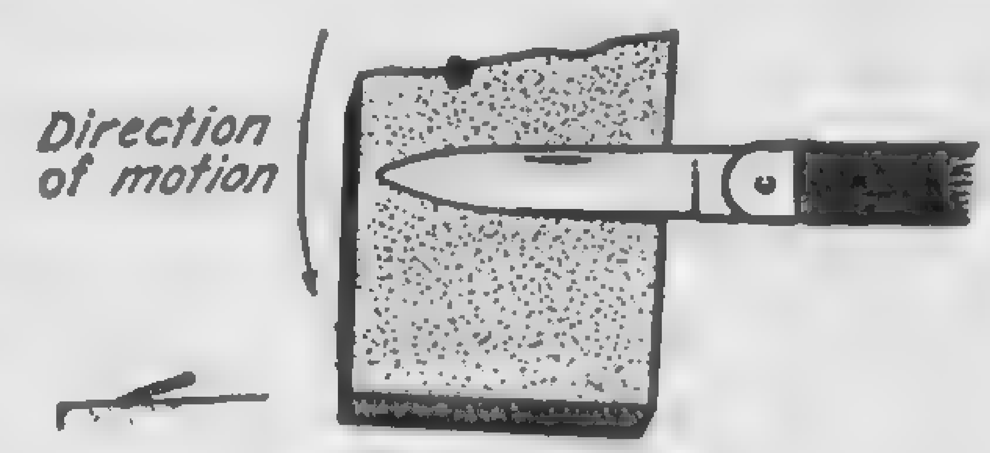


Fig. 102

If the knife is badly knicked, it must be ground on a grindstone (not an emery wheel) using plenty of water. Be careful not to spoil the temper of the steel by using too much pressure.

**Planing a Small Board to Dimensions.** The following paragraphs, together with Fig. 103, explain how to true a board to specified dimensions.

*1. Make a Working Face.* Select the best side and plane it flat and true. Test with the try square, plane out any warps or twists, and mark it with a pencil line, as shown in Fig. 103, to indicate it as the working face.

*2. Make a Working Edge.* Plane one of the narrow sides or edges straight and square with the working face. Test with a try square. Be sure that the head of the try square fits snug against the working face. Mark this edge with a pencil mark to indicate that it is true and may be used as a working edge.

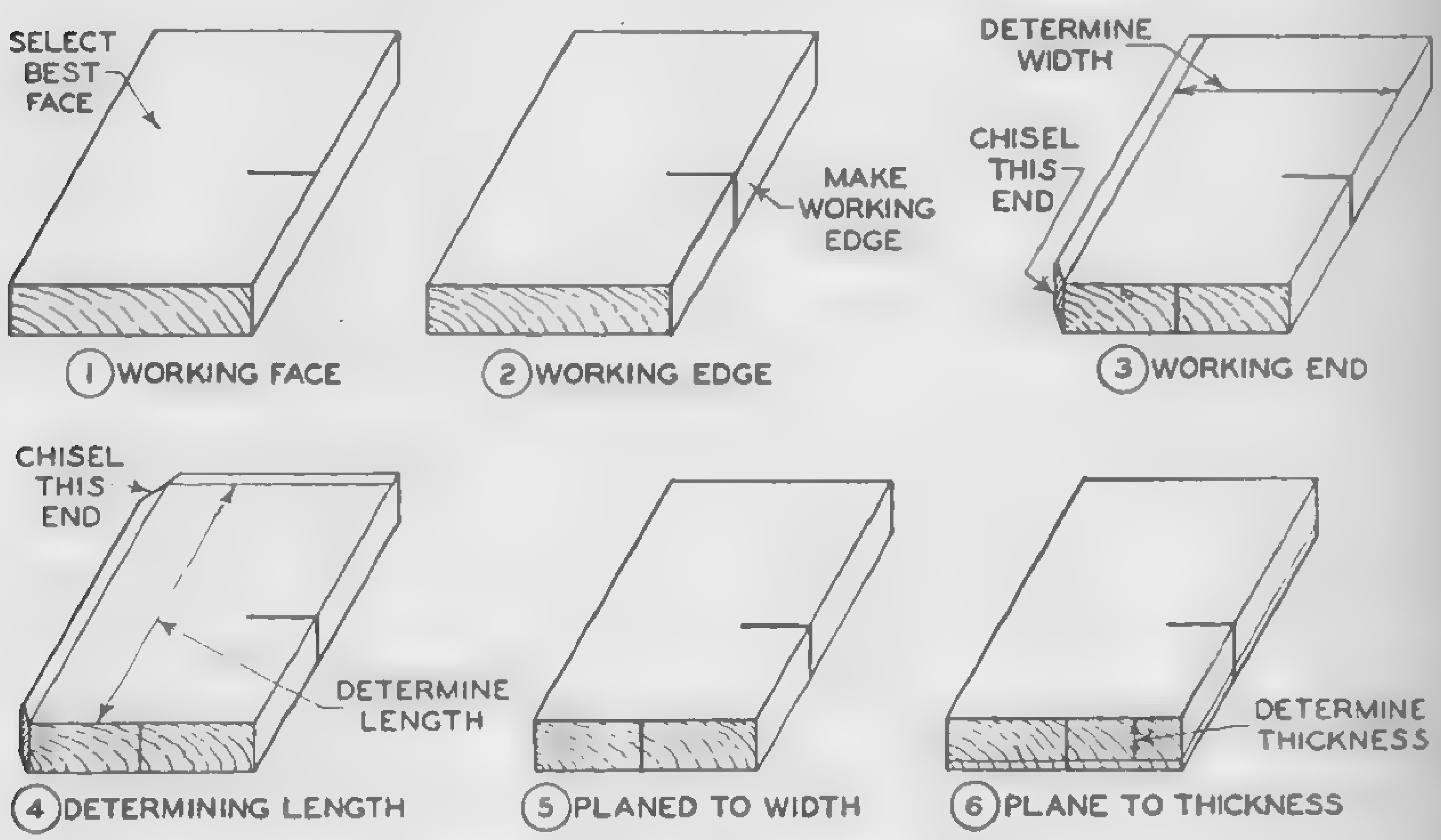



Fig. 103. Method of Truing a Small Board to Dimensions

*3. Working End.* Mark the final width of the board from the working edge using a marking gage; or measure two parallel points, one at each end, and draw a pencil line through the points. Chisel off one corner outside the gage line to prevent chipping. Plane this end smooth and true with a block plane, making it square with both the working face and the working edge. Mark this end with a pencil.

*4. Cutting the Board to Length.* Measure the length from the working end, draw a line and square it with the aid of a try square, making sure that the head rests firmly against the working edge. Chisel the corner as shown. Saw off the surplus wood by the aid of a backsaw or a fine-tooth cross-cut saw, just leaving the pencil mark on the board. Plane this end true and square to



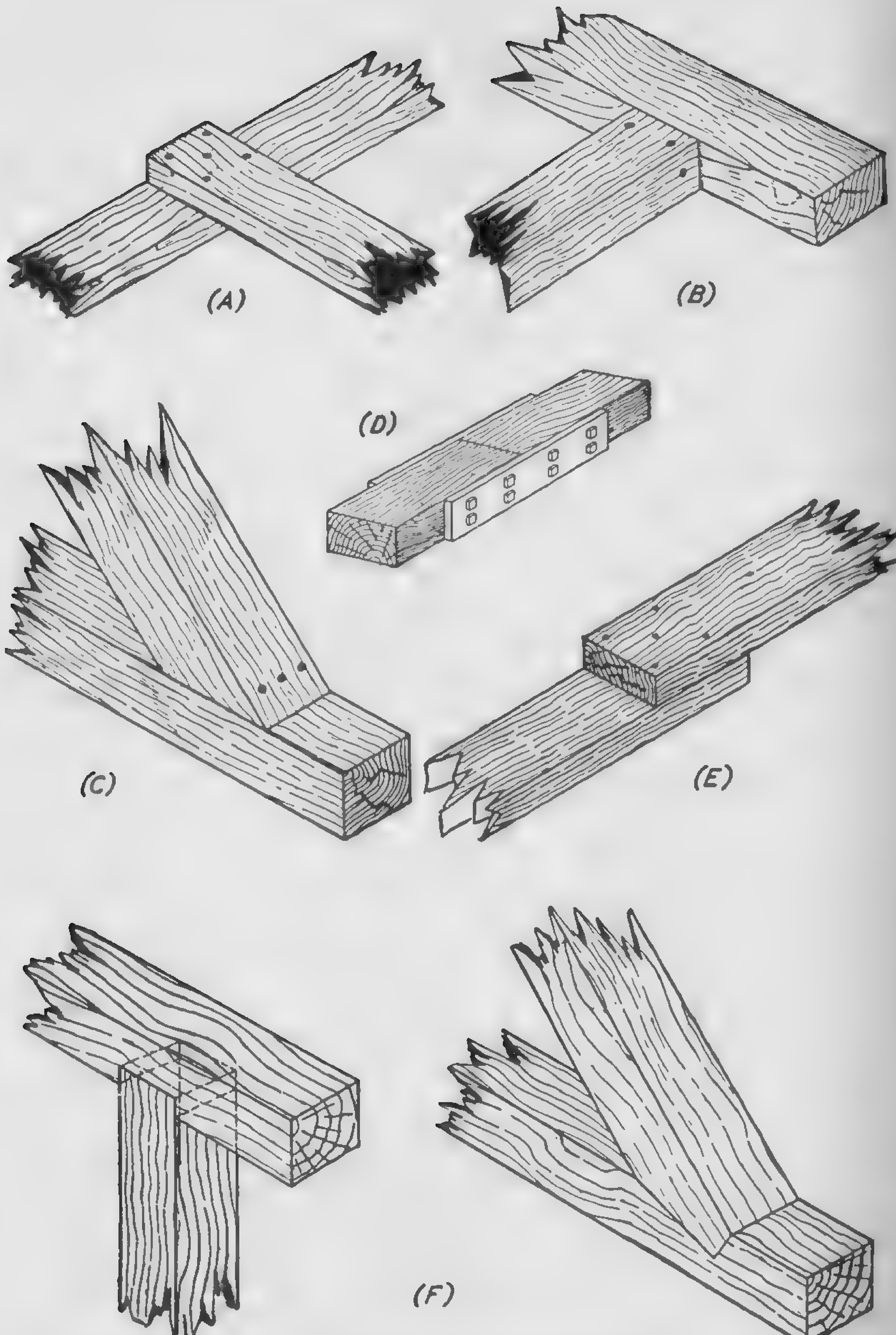


the working face and the working edge, using a try square for testing.

*5. Planing the Board to Width.* If there is more than three-eighths of an inch of material to be removed, saw this off by use of a rip saw. If not, plane the board down to the line, making sure that the edge is square to the face of the board, using the try square for testing.

*6. Planing Board to Thickness.* The thickness of the board can now be marked off with a marking gage and the board planed down to the gage line.

These same steps are used in bringing a large board down to size, although in most cases it is not necessary to take twists or winds out of the working face of the board because in all probability it will be fastened to some framework which will correct any warping that may be in the board and hold it in shape. A table top is a good illustration of a large board kept from warping by being fastened to the frame of the table.



JOINTS AND SPLICES. (A) PLAIN JOINT; (B) SQUARE BUTT JOINT; (C) OBLIQUE BUTT JOINT; (D) BUTT JOINT WITH PLATES; (E) SPLICE; (F) SPECIAL SQUARE AND OBLIQUE BUTT JOINTS





PART 5

# Painting—Wood Preservation

## KINDS OF PAINT

The various kinds of paint number into the hundreds and would require a large volume to describe them all. However, the commonly used varieties are described here for the reader's general information. In presenting such a discussion, this volume does not imply that one paint is better than another. The discussion is purely from the standpoint of describing *typical* kinds of paint.

**Oil Paint.** An oil paint is a paint in which the vehicle (liquid portion) is a drying oil of some kind, such as linseed oil. This oil is used to a great extent because it naturally absorbs oxygen and in so doing changes from a liquid to a solid. Most oil paints use either raw or boiled linseed oil. This mixture makes a desirable paint for interior use.

Driers and thinners are used to modify the oil. Turpentine makes the best thinner because it tends to dissolve the materials in the paint, and it also dissolves the resin in wood in cases where it is applied to wood. The dissolving of resins in wood surfaces brings about a greater penetration and adds to the paint's adhesive ability.

Driers, such as litharge, manganese dioxide, liquid japans, and lead and manganese compounds are used in paint to quicken the hardening. They do this by tending to hurry the joining of oxygen from the air with the linseed oil.

Pigments used in oil paints generally are lead and zinc. They form the bulk of the paint and supply the coating properties.

Paints can be purchased either *ready to use* or *mixed on the job,* as preferred.

**Graphite Paint.** Graphite paint is made by mixing linseed oil with flake graphite. The graphite causes a slow drying of the oil and the small amount of silica, usually with the graphite, gives final hardness to the paint.

**Water Paint.** The difference between oil and water paint is that in water paint the vehicle is water. Such common items as calcimine, whitewash, etc., are typical water paints.

Most calcimine consists of powdered white chalk, pigment, and glue or casein used as a binder. The pigment in this case is in the form of a powder instead of an oil, as used with oil paints. Whitewash is made simply by shaking quicklime in water.

There are various other water paints, all used as interior finish, which are especially suitable for spraying interiors.

**Water-Thinned Paints.** Water-thinned paints have vehicles of a protein base, derived from compounds found in certain plants and in milk. They are produced first in a dry powder form. In this state they readily combine with water. When the water evaporates, a chemical change takes place, so that the vehicles form a tough transparent film thereafter insoluble in water. The pigments used in water-thinned paints are the same as used for oil paints and water is used as a thinner in place of oil or turpentine. These paints dry quickly and in themselves are fireproof.

**Varnish.** Varnish is a mixture of resin in alcohol or drying oil. It contains no pigment and after application hardens to a smooth and shiny surface by the evaporation of the vehicle. Some varnishes such as oil are mixtures of resin and boiled linseed oil.

Varnishes are manufactured with special uses in mind. For example, there are floor varnishes, rubbing varnish, spar (exterior) varnish, interior varnish, and flat (no gloss) varnish.

**Shellac Varnish.** Shellac varnish is made by dissolving either white or orange shellac in grain or wood alcohol. This shellac varnish produces a pleasing finish that has a dull luster.

**Shellac.** Shellac is made by refining seed lac. Its natural color is orange although sometimes it is made white by bleaching. The material lac is a resin, in nature, exuded by certain kinds of insects on twigs of trees.





**Lacquer.** Lacquer is a composition of nitrocellulose, resins, solvents, and softeners. All these materials add to the quality of the lacquer in that nitrocellulose makes it tough; hardness and luster are brought about by the resin; and elasticity is given by the softeners. Alcohol is used as a solvent. Castor oil can be used as a softener. The nitrocellulose is made by treating cotton of short fibers with nitric acid.

**Japan.** Japans may be put in two distinct classes. First, there is painter's japan—a varnish which consists of solutions of metallic salts and resins in a drying oil. Second, there are decorative japans which are opaque varnishes containing asphaltum and which are designed to produce a high luster on the surfaces of woods and metals.

**Enamel.** This can be called an actual paint, since it contains pigment and a vehicle. Enamels are pigment varnishes; the base pigments are white, different colors being added to give the desired tint, and the vehicle is varnish. This combination of pigment and varnish produces a surface that has ample luster. Some enamels are made of lacquers mixed with colored pigments.

**Aluminum Paint.** Aluminum paint consists of a finely divided pigment mixed with a vehicle. The aluminum pigment particles which are in the form of minute flakes are arranged in the paint film in more or less parallel layers. Vehicles for aluminum paint generally are a drying oil-resin base, nitrocellulose, and pitch or asphalt.

**Stains.** Stains are obtainable in four different kinds, namely, oil, water, spirit, and chemical stains.

Oil stains have an oil vehicle to which can be added turpentine which is a solvent and helps to increase the penetration. The coloring may be done by using pigments or aniline dyes.

Chemical stains, as their name implies, do their staining by means of chemical changes produced by the action of such chemicals as iron salts, potassium, zinc sulphate, etc., dissolved in water. Thus no coloring matter is required. The chemicals act on the woods and change them to various colors depending on the chemical and its action on the wood.

Water stains are solutions of aniline dyes and water.

Spirit stains contain alcohol, for example, in place of water.

## PAINTING

**Preliminary Preparations.** New houses, never before painted, should be allowed to dry out for several weeks after the plastering has been done. "Green" plaster is always moist, and time is required for it to dry properly. Delay the paint job to make certain the boards do not retain this moisture.

Knots and resin streaks should be sealed to prevent later discoloration of the paint film; best results are obtained by giving all knots and resin streaks a coat of aluminum paint. This tends to conceal these spots and check "bleeding" through of stains and resins.

Houses that have been painted before must have all loose, scaly paint scraped off with either a putty knife or wire brush. Paint that is merely "chalking" or slowly wearing away need not be removed as it offers the firm foundation required for new paint. Cobwebs, dust, and other foreign matter should be brushed off with a duster as you apply the first coat.

There are several incidental but important odd jobs you should do before beginning the actual painting. For instance, loose boards, cornice moldings, and door or window trimming should be gone over, nailed up, and put in good condition so that they can be properly painted and not marred by later repairs. Any new boards that you must insert should be given an individual priming coat before the finishing coats. Otherwise they will flatten out and not show the glossy body of the rest of the paint job.

Eave spouts, conductor pipes, and gutters should be examined for rust and replaced if badly rusted, or cleaned and painted over if only slightly rusted. Use a wire brush to remove the rust and provide a better painting surface. Roof and gutter paints are made especially for resisting rust on metal surfaces. For unpainted metal, a tinners' special lead chromate paint is the most effective primer. Paint downspouts the same color as the background of the house to keep them inconspicuous . . . the same as the trim if the spouts are against the trim.

Window glass should be replaced before painting so that the putty will be painted over with the trim. Putty applied later would look unsightly on freshly painted window sashes. A general





replacement of old, dried, cracked, or loose putty will prove worth the effort at this time. Before putting in the putty, old sashes that are badly weather-beaten and extra dry should have a priming coat of house paint (thinned with linseed oil) brushed into the putty grooves.

The roof and chimney should be examined carefully; loose or missing shingles replaced, window frames calked, brick joints around the chimney flashings cemented up, and the whole chimney tuck-pointed where needed. An asbestos fiber roof cement proves most practical in making many chimney repairs and for stopping leaks in flashings, also in roll roofing or composition shingles. Places around doors or windows that might let moisture get in should be thoroughly calked.

The purpose of all these preliminary repairs is to avoid leaks which will mar interior decorations or result in paint peeling due to water getting behind the painted surface.

**Choosing Brushes for Exterior Painting.** One large brush for regular work (*3* of Fig. 1), a smaller brush for trimming (*1* or *4* of Fig. 1), and a sash brush (*5* of Fig. 1) will be needed. (An oval brush as in *2* of Fig. 1 is used for varnishing floors.) The average

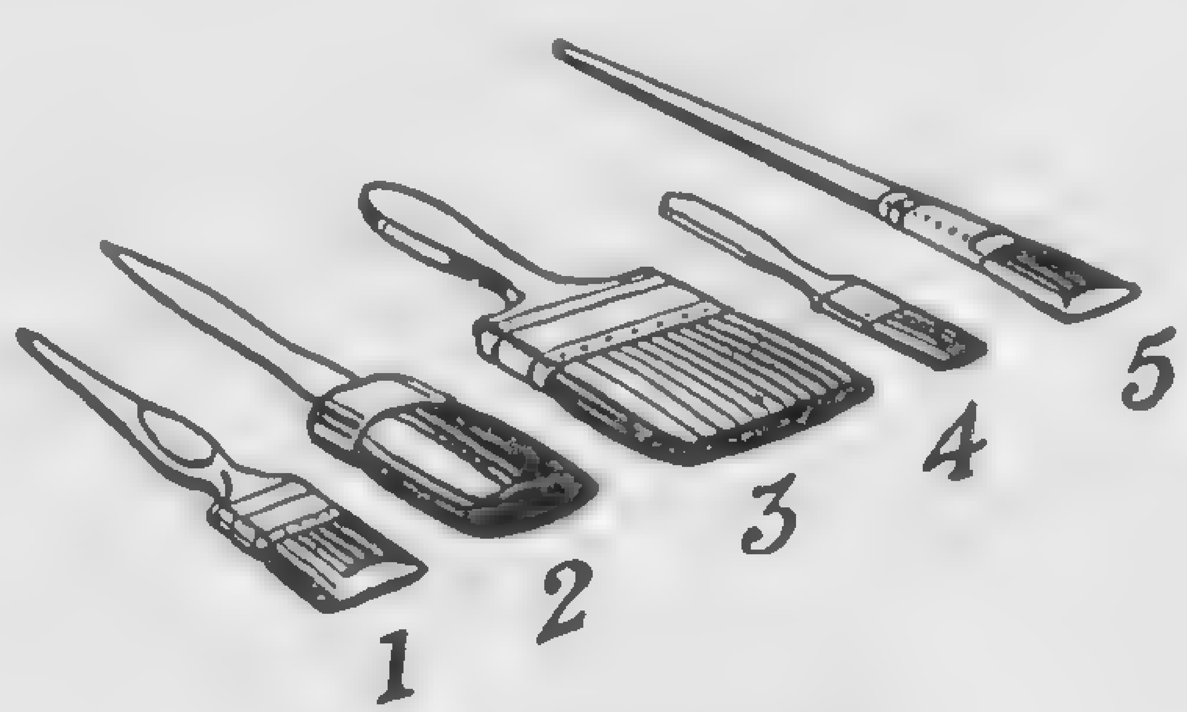



Fig. 1. Types of Brushes

person finds a flat brush about 3½″ or 4″ wide best for ordinary painting. For general trimming, a flat brush about 3″ wide is recommended. A long-handled flat brush 1″ to 2″ wide will be found suitable for sashes. Brushes with longer bristles when filled with paint are usually too heavy for untrained wrist muscles to handle. The "spring" of the long bristle brush, and its extra paint-carrying capacity are desirable characteristics and therefore pre-

ferred by the experienced painter who is accustomed to these heavier tools and can handle them without difficulty.

Here are a few helpful suggestions:

1. Before putting a new brush into work "whip" it back and forth over one hand to remove any bristles which might not be caught into the rubber setting and to remove dust which is even in new brushes; see Fig. 2.

Fig. 2

2. Enamels or varnishes should be "flowed" on the surface by means of a soft, even, long stroke. By all means refrain from using a "scrubbing" action as this will introduce air bubbles into the finish.
3. Brush with the grain, not against it.

It pays to buy good brushes and take proper care of them. They will produce better and faster work and last longer.

**Additional Needs.** Besides the assortment of brushes described, you will need putty, a putty knife, sandpaper, and a paint paddle. A stiff wire brush is useful in removing loose, scaly paint on old painted surfaces. Linseed oil and turpentine are needed to thin according to directions. At least one ladder will also be necessary.

**Thinning House Paint.** There are two distinct types of house paint now in use. In order of importance they are—regular house paint and the nonpenetrating house paints.

With the regular type of house paint, the first coat is generally reduced with linseed oil and turpentine in order to secure proper anchorage of the film and to revive the old and porous surfaces which are thirsty.

Nonpenetrating types of house paint and undercoat require no thinning. The manufacturer's directions in all cases—whether for the regular house paint or the nonpenetrating type—should be followed to the letter. Proper application of the priming coat is one of the most important parts of painting.

**Treatment of Old Painted Surfaces.** When a three-coat job is to be done, the thinning of the priming coat is usually a little different from that of a two-coat job. On a three-coat job, linseed oil and turpentine are usually added to the priming coat in order





to revive the old thirsty fibers of the exposed wood and the chalking paint film, as well as to give proper anchorage or adherence.

For the second and third coats, it has been found by both the manufacturers of high-grade paint products and certain branches of the Department of Agriculture that best results can be secured when these two coats are so applied that when the drying is complete there is the same ratio of linseed oil to white lead, zinc, and other pigments in both the second and finishing coats. If this practice is not followed, and more linseed oil and turpentine than recommended in label directions are added, a premature breaking down of the finishing coat of any house paint may result, as it will only result in excessive chalking and washing of the film and shorten the life and protective qualities of the paint job.

On two-coat work the first coat should be thinned according to the manufacturer's directions. Allow the proper thinning for the type of surface to be covered—to illustrate: under a roof, or under the eaves, where the surface is hard, smooth and slightly weathered, additional turpentine should be added in order to give the paint a better grip. House paint for a surface in very good condition, will require a different amount of thinning from a surface in poorer condition. The final coat should not be thinned.

**Treatment of New Work.** All soft, pitchy, and resinous spots should be properly primed with aluminum paint or similar materials to seal in the resins which come to the surface from continuous exposure to the rays of the sun.

New clear wood absorbs a greater amount of linseed oil than previously painted surfaces. On the other hand, where the wood is extremely pitchy, it is advisable to add more turpentine than on a very clear grained wood surface, in order to cut the natural resins in the wood and give proper adherence.

When painting any type of exterior surface, it cannot be too strongly emphasized that the manufacturer's directions should be followed. In case conditions arise which seem to be out of the ordinary in type, the manufacturer is always glad to assist in solving your problem.

**Mixing of Paint.** The paint must be stirred thoroughly. When you remove the lid on the paint can, you will find the oil at the

top and the heavier pigments settled to the bottom. The oil is the vehicle which uniformly disperses or spreads the pigments over the whole surface. You must thoroughly stir these pigments into the oil to make the mixture uniform. A wooden paddle, about two inches wide, serves quite well.

To stir properly, pour off the surface oil into an empty bucket (No. 1 in Fig. 3), then pour back a little at a time into the paint as the stirring progresses, keeping the mixture uniform at all times (No. 2 in Fig. 3). Finally, pour the whole mixture back and forth from one container to another several times (No. 3 in Fig. 3).

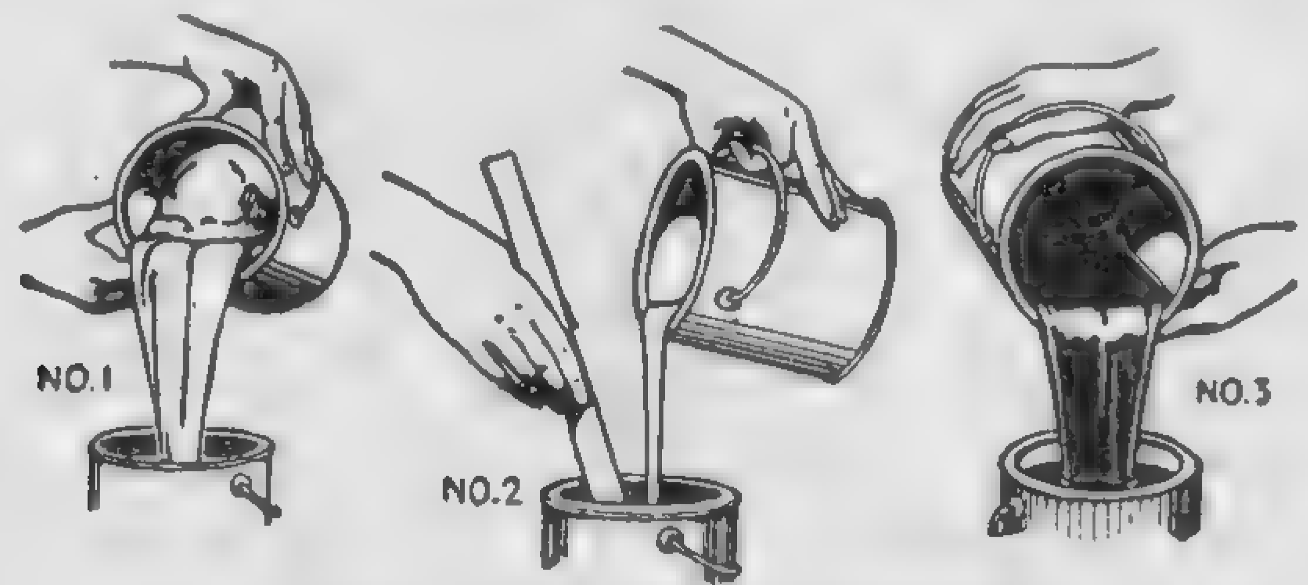


Fig. 3. Three Steps in Mixing Paint

With this even mixture, you are now ready to begin painting. A half-hour's stirring of a 5-gallon can of house paint is not excessive.

**Number of Coats.** The number of coats depends upon surface condition and type of paint used. If it is new wood or badly weathered, three coats are advisable. Over old painted surfaces in fairly good condition, two coats will give good results.

**Quantity of Paint.** Every full gallon of any paint contains 231 cubic inches. Disregard extravagant claims for "spread" or coverage capacities of various paints made for the same purpose. Quite plainly, the larger the area a gallon covers, the thinner the film coating with correspondingly less protective resistance—though the decorative and color value may be the same. The first purpose of paint is to protect, and all reputable paint manufacturers have that thought first in mind.

In order to estimate the amount of paint required, you must first estimate the number of square feet to be painted. This can be done as follows: Multiply the distance (in feet) around your building by two feet more than the height to the eaves. Add to this result the number of square feet in the gables, which is found





by multiplying the height of each gable by one-half the width. Divide the total square feet to be painted by the number of square feet one gallon will cover. This will give you the number of gallons required for your paint job.

For houses, allow one gallon for trim to five gallons of body paint. Barns and such structures generally require only one gallon of trim color for ten gallons of body paint.

New clear wood absorbs a considerably greater amount of linseed oil from the priming coat than previously painted surfaces. Therefore, more linseed oil is added to the first coat to be used in new clear wood than any other type of surface.

Previously painted surfaces in fair to good condition require the addition of relatively little turpentine and no linseed oil to the ready-mixed paint, inasmuch as there is practically no absorption from the new film into the old film.

No thinner should be used in the finishing coat of any house paint, as it will only result in excessive chalking and washing of the film and shorten the life and protection of the paint job.

When using controlled penetration type paints, the product is formulated to be used as it comes in the can so as to give proper adhesion to the surface coated and should not be thinned under any circumstances. This type of undercoat is followed by a coat, or coats, of regular house paint.

Aluminum paints are highly recommended for priming unpainted surfaces. Two coats of house paint should then be applied.

Thinning directions are usually stated specifically on the label of each can of paint, and for best results they should be followed closely. *It is false economy to add excessive thinner to any paint product to secure greater coverage. Protection and beauty are short-lived when this is done.*

**Typical Instructions on How to Thin Each Gallon of House or Barracks Paint**
(For Two-Coat Work)

| Kind of Surface | Raw Linseed Oil First Coat | Raw Linseed Oil Finish Coat | Turpentine First Coat | Turpentine Finish Coat |
|---|---|---|---|---|
| Fair to Good (*Painted*)..... | 0 | 0 | 1½ Pts. | 0 |
| Badly Worn (*Painted*)....... | 1 Pt. | 0 | 1 Pt. | 0 |
| Badly Worn (*Unpainted*).... | 1 Pt. | 0 | 1 Pt. | 0 |
| New Clear Wood........... | 3 Pts. | 0 | 1 Pt. | 0 |
| New Pitchy Wood.......... | 1 Pt. | 0 | 3 Pts. | 0 |

**Where to Begin.** Begin at an upper right-hand corner of the building. Try to finish a day's work at a corner or window to avoid laps and streaks. The place where you leave off one day's work and begin another will not then be noticeable, even though several days may elapse because of weather delays.

Paint west or north sides during morning hours, east or south in the afternoons, so that strong, direct sun will not blister the wet paint. You will find such a working plan more agreeable and comfortable for yourself as well. Begin at the top and paint down so that splashes will not damage the surface below. Allow four to six days, or longer if necessary, for each coat to dry.

**Painting Barracks and Barns.** To fill the demand for a paint for barracks, fences and outbuildings, paint manufacturers have prepared a special paint compounded from metallic oxides, offered in a limited range of colors and sold at a much lower price per gallon than house paint. The durability and appearance of such paints are satisfactory for the purpose intended, and the lower price makes them economical to use. They cannot, however, compare with fine house paint in either durability or appearance. If you are particular about your barracks and outbuildings and wish to secure the greatest durability and the best possible appearance, use either regular house paint or the better grades of barn paints which are made to stand up like a house paint.

When painting a barracks, as in all other painting, be sure the surface is perfectly dry, and it is good painting weather. Paint will never stay on a wet or damp surface. Follow the directions given by the manufacturer in detail.

**Preparing and Painting Cement Floors.** If new or unpainted, they should first be washed with a solution of zinc sulphate—3 lbs. dissolved in a gallon of water. This neutralizes the free lime. When dry, rinse off the excess zinc sulphate crystals and apply a coat of cement primer. The primer provides better adhesion for the finishing coat. After the priming coat is thoroughly dry, the regular floor paint or enamel should be applied.

**Paint for Porches, Floors, or Steps.** *A specially designed product with a varnish base should be used.* House paint is made with linseed oil as a base and to withstand weather only and not constant foot friction to which a porch, floor, or steps are subjected.





Porch and floor paints and enamels are made to withstand both destructive weather and constant wear. They usually dry quickly and form a tough film that can be walked on or scrubbed regularly. Nail holes and cracks should be filled with a good crack and crevice filler before painting; see Fig. 4. All wooden porch floors that have been painted should be repaired before repainting. It is advisable to thin a small quantity of the paint to be used with turpentine and apply it to the new wood used in repairs, worn spots, edges of the steps, etc., where the paint is entirely worn away. Allow these patches to dry and then apply one or two full coats of the floor paint or enamel just as it comes in the can.

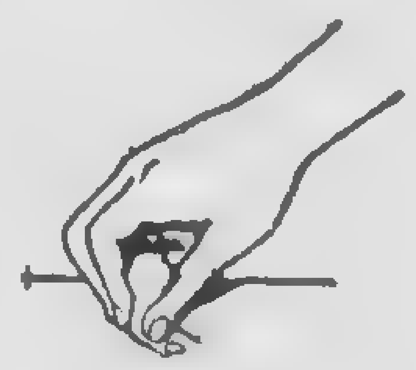


Fig. 4

There should be sufficient ventilation under all porches and steps, otherwise moisture will accumulate and the paint is likely to peel.

**Preserving Wood from Decay, Insect Pests.** Pure creosote oil wood preserver is the best preservative you can use to coat wood surfaces to be sunk into the ground, such as fence posts, building timbers, and foundation supports. Creosote oil is recommended by the U. S. Department of Agriculture as more effective than coal tar and more economical in actual practice than other preservatives. Creosote oil wood preserver penetrates deeply, and stops the destructive action of decay, worms, and termites.

**Refinishing Trucks and Tractors.** It should be remembered that trucks, tractors, and implements must undergo very hard usage. They are not stationary like houses, and not protected like walls. Therefore, ordinary house paints or interior enamels should not be used on such equipment. Always insist on specially prepared paint for use on wagons, tractors, and implements. It is formulated with special tough resins and oils to withstand rough usage and exposure. Ordinary paint subjected to such conditions would soon break down, and fail to give the protection you want. That's why it is so important to choose the right kind of paint for your job.

Wagons, trucks, tractors, and other implements do not usually need any preparation for painting other than a thorough cleaning. If you are planning to do a very careful job of painting, you should remove the gloss of the old finish and the rust from the

metal parts with fine sandpaper or steel wool. Then, apply one or two coats of truck and implement paint with a medium-sized brush, or with spray painting equipment, if you prefer.

Where it is only desired to touch up parts of the vehicle or implement which are not rusty, it will not be necessary to use sandpaper. Simply clean the surface to be touched up with turpentine, and apply the truck and implement paint as outlined.

**How to Avoid Paint Troubles.** If you would avoid paint troubles, always remember that the success of every painting job depends on seven things.

Here are the seven:

1. The condition of the weather at the time of painting
2. The kind and condition of the surface to be painted
3. Proper stirring and accurate following of all thinning and label directions
4. The conscientious carefulness of the painter in putting on the proper number of coats, brushed out or sprayed on evenly
5. The length of time allowed between coats for drying
6. Proper repair of construction defects before painting
7. The quality of the paint

You can spoil any painting job, even though you use the best paint in the world, by not putting it on right.

## BRUSHES, THEIR CARE AND USE

A good brush will last the average home owner a long time if it is given a little care. It pays to purchase quality brushes and to spend the five or ten minutes required to put them away properly when you have finished painting or varnishing. Even if you do not worry about the cost of the brushes, you will be well repaid in the pleasure of finding them in good shape the next time you want to use them. To do good work, you must have good, clean brushes.

**Varnish or Enamel Brushes.** For varnishing, always use a new, clean brush or one that you keep purposely for varnishing. *Don't use an old paint brush!* Brushes are thoroughly cleaned and washed at the factory, yet dust may have settled on them before





you are ready to use them. To insure that no dust particles get into the varnish or enamel from your brush, dust it out and wash with turpentine before starting the job. If the brush is one that previously has been used, be certain there is no old, dried varnish on the bristles or you will have trouble with specks in the finished work.

After you have started to varnish or enamel, if you intend to leave the work overnight, put the brush in a can of turpentine or paint thinner. You will find it convenient to keep a can of turpentine always on hand. Before using the brush again brush it out thoroughly to get the turpentine or paint thinner out, and work the varnish or enamel into the brush thoroughly before you continue with the job.

When you have finished varnishing or enameling, clean the brush out thoroughly with turpentine, benzine, or kerosene; then wash with warm soap suds, rinse in clear, warm water and shake the brush well. While it is still damp, smooth the bristles down carefully and wrap in heavy paper which should be tied on at the ferrule. Store in a dry, cool place.

Lacquer brushes should receive the same treatment with this exception—lacquer thinner should be used to clean the bristles before washing with soap and water.

Should you neglect to clean your brushes and they become hard and seemingly useless, don't throw them away. Liquid brush cleaner will quickly revive brushes to service again. It leaves bristles soft and pliable and will not harm bristles, hands or clothing.

**Proper Way to Brush Varnish and Enamel.** Varnish and enamel should never be brushed out like paint. When varnishing or enameling, fill the brush and apply quickly and freely, "flowing" the liquid *with* the grain of the wood. Next, without filling the brush, stroke directly *across* the grain. This will help spread the varnish or enamel in an even film, covering any spot missed in the first application.

Now scrape the brush until it is fairly dry over edge of the can, and *brush lightly once more with the grain,* making your brush strokes as long as possible to take up any surplus varnish or enamel which would otherwise run and make sags.

Choose a clear, dry day for varnishing or enameling; and after applying, avoid direct drafts or otherwise stirring up dust which will settle on the wet surface and spoil the finish.

**Paint Brushes.** Remove any loose bristles from a new brush by simply running your fingers through the bristles three or four times. If you want to put a paint brush away overnight during a painting job, it should be placed in turpentine or raw linseed oil, ferrule deep; see Fig. 5. When you have finished painting, follow the preceding instructions on the care of brushes. This will prolong the life of your paint brush.

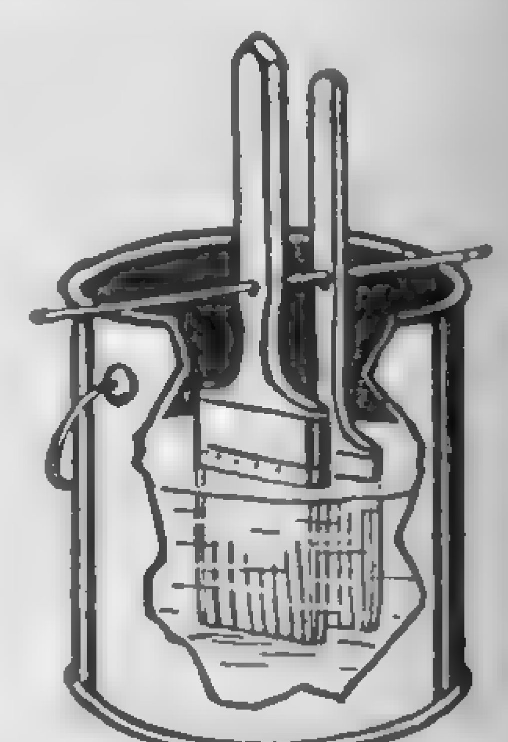


Fig. 5. Care of Brush

**Brushes to Use When Painting Walls and Ceilings.** For applying inside wall paint we recommend a 3″, 3½″ or 4″ width brush. This brush should be of the same type ordinarily used for applying exterior house paints, and the width used should be determined by the strength and experience of the operator. For the application of enamels, we recommend ordinarily that a smaller brush of the same type be used. Because of the varnish content in an enamel which has a tendency to "pull" and tire the arm of the operator, a 2½″, 3″ or 3½″ width brush is our recommendation for enamel application, depending on the strength and experience of the operator.

**Calcimine Brushes.** Remove any loose bristles from a new brush. After each day's use, calcimine, whitewash, and paste brushes should be washed thoroughly with warm water and hung up to dry with bristles downward. A good brush will last the average user a long time if it is given a little care. When you have finished calcimining, you'll find it will pay to spend five or ten minutes in properly cleaning and putting away the brush.

**NOTE**—*It is never advisable to leave brushes in water. The water may cause the handle to swell and split the ferrule. If left for any length of time, the water will destroy the elasticity of the bristles, and cause them to become flabby.*

**How to Use a Brush.** Grasp a brush firmly by the handle—hold it just above the bristles. Keep the handle as nearly as possible always perpendicular to the surface. Press down firmly if spreading paint. Ease up and brush a little slower with varnish or enamel. These materials should be "flowed" on with a long, even stroke. Excessive brushing tends to create air bubbles in the finish. Don't try to cover a large surface with one brushful. Just dip far enough into the paint—a half inch to an inch or so—to take up a load that will not drip on the way. Always start a new brushful a few inches from completed portion and end up by brushing into finished part. On wood surfaces the last strokes should be in the direction of the grain.





**How to Choose Right Brush.** Here is a simple guide to aid you in your selection of the proper brush.

For painting *outside surfaces,* use a brush 3½, 4, or 4½″ wide.

For painting *inside surfaces,* use a brush 3, 3½, or 4″ wide.

For painting *floors and porches* use a brush 2½, 3, or 3½ inches wide.

For painting *woodwork* or trim use a brush 2 or 2½″ wide.

For finishing *furniture* and smaller pieces, use a brush ½ to 2 inches wide.

If you are applying *calcimine* or casein paint, use a calcimine brush, 6 or 7 inches wide.

For applying *liquid roof coating* to a roof do not use a paint or calcimine brush. Use a regular roof brush. You can insert a broom handle into these brushes for handy use.

If you are applying aluminum or gold color enamel to *radiators, household articles, etc.,* use a soft goat hair bronzing brush.

To aid in obtaining a neater job when trimming sash, long handle sash brushes are available.

In selecting a brush it is well to remember that there are two factors contributing to the success of every paint job: good paint material and proper application of that material. A brush properly selected for the job at hand will not only make the application of the paint or varnish easier but will also add to the appearance by the smoothness of the finished surface which is obtained. The medium to longer length bristle brushes hold more material, reduce the number of times the brush is dipped into the paint and thus save time. Longer bristles are more flexible and insure a smoother application and longer wear.

## PAINTING WITH SPRAY GUN

Spray painting can be done on large and small articles alike and with the same equipment. You don't need to be a professional painter to spray paint. Most of the material available today can be sprayed with equipment which will produce air pressures from 30 to 45 lbs. Spray guns are designed to handle materials at these pressures and very successful work can be done.

Ordinarily, spraying is from six to eight times as fast as applying paint with a brush and, on some surfaces, even faster.

The first step in spray painting is to see that the surface or article is free from all wax, grease, loose paint, and dirt. If the surface is rough, it should be smoothed with steel wool or sandpaper (except stucco, or other surfaces intended to be rough). After the spraying material is thoroughly stirred, it should be strained through cheesecloth or similar loosely woven fabric to remove any foreign particles which may have collected during the stirring operation, and which might plug up the small openings in the spray gun. The spraying material should then be put into a spray cup or a larger container, such as a 3-gallon paint tank.

In spraying cold-water paint, proper straining is very important as these materials are mixed (not ground) and unless the coarser particles are removed a clogging of the nozzle will result.

It is advisable to experiment a little on an old wooden box, piece of wood, or something of that nature until you have mastered the simple technique of handling the gun. The spray gun should be held from 6″ to 10″ from the work and carried along the surface in an even stroke, the pressure on the trigger of the gun being released before the hand stops moving at the end of any stroke. This is done to prevent a piling up of the spraying material which will occur if the pressure on the trigger is not released when the movement of the gun is stopped.

It is important, in spraying any type of finishing material, that the spraying equipment be of a type that no oil will get into the finishing coats. If oil used in lubricating the equipment contaminates the finishing material, it will not dry properly and may present a spotty appearance due to small particles of oil being in the film.





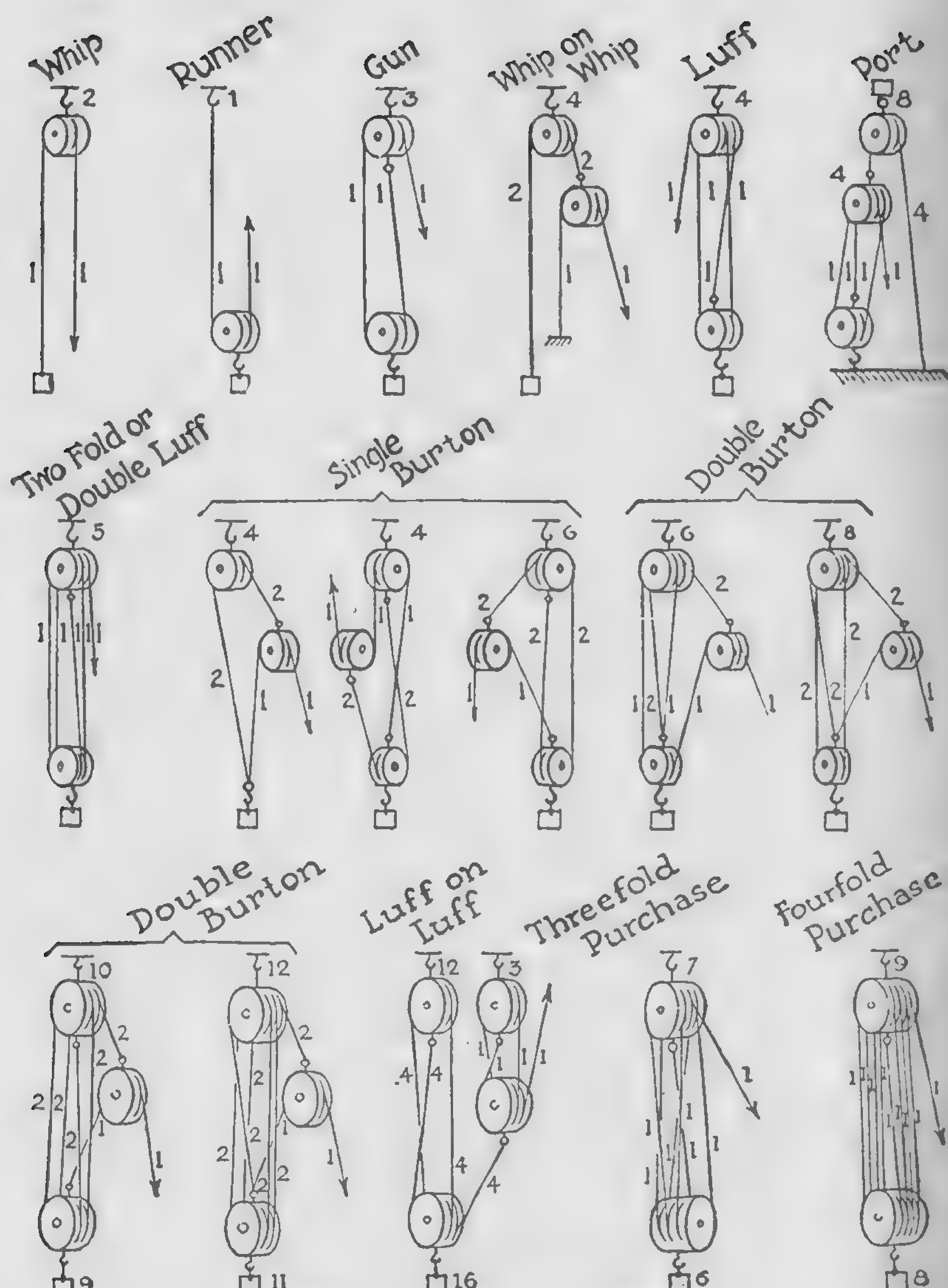
## CAMOUFLAGE AND BLACKOUT PAINTS

The knowledge and development of camouflage practices acquired during the first World War were lost sight of and only a few men kept up their interest in the subject, so that it became almost a lost art. Also, many of the previous conceptions are today outmoded by present attack techniques. Our active entry into the present conflict caused the Army, the Navy and the Air Corps to enlist the services of specialists possessing the technical knowledge for designing day and night camouflage.

There are, roughly, four stages of camouflage. *No. 1* is the first or lower visibility stage. This stage involves the use of dull camouflage paints to suppress high visibility color. *No. 2* stage includes the making of patterns with paint to imitate the general pattern characteristics surrounding the object to be camouflaged. *No. 3* stage involves the distortion of cast shadows, the introduction of some false angles and distortion of shapes by screening, and the altering of highly reflective smooth surfaces by applying a rough texture to them. *No. 4* is the "all out" camouflage where the object is totally concealed against the pattern of its background from the air. This incorporates the building of false roofs, dummy objects or buildings, camouflaged so as to decoy the bombardier into aiming at them instead of at the real target; the planting of trees and bushes and the visual trick of running roadways across the top of factories, as if they were not there.

Camouflage and blackout paints come in black and white, and in such soft colors as light green, sand, earth brown, loam, olive drab, dark green, field drab, earth yellow, and earth red.

Special camouflage and blackout paint is made for windows and skylights. This comes in black, smoke gray, earth drab, and neutral brick.



BLOCK AND TACKLE COMBINATIONS



**PART 6**

# Rope, Splices, and Knots

## GENERAL INFORMATION ON ROPE

**Terms Used in Manufacture of Rope:**

*Fibers.* Materials from which yarns are spun

*Strand.* Yarns twisted together

*Rope.* Strands twisted together

*Laying.* The process of twisting strands together in making rope

**Terms Used in Handling of Rope:**

*Bight.* A section of the rope turned back on itself

*Turn or Loop.* A turn on a rope with the ends extending in opposite directions

*Round Turn or Bend.* Any turn in a rope around itself or some other object

*Knot.* A combination of bights and turns arranged so the tight part of the rope will bear on the free end of the rope

*Hitch.* Attaching a rope to an object so it may be readily detached

*Half-Hitch.* A turn of the rope arranged so a section of the turn will bear on another section of the turn

*Haul.* Pull on a rope

*Running Part or Fall Line.* The free end or that part of the rope that is hauled upon

*Standing Part.* The stationary end or that part of the rope that is tight

*Seized.* Two parallel ropes bound together

*Served (whipped).* The end of a rope wrapped to keep the strands from untwisting

*Splice.* Two ropes joined together by interweaving the strands

*Taut.* Hauled tight or under tension

**Standard Manila Rope.** Manila rope is furnished in the following sizes and each size may be obtained in coils up to 1,200′ in length.

TABLE 1

| Size, (Diameter in Inches) | Breaking Strength, New Rope (Lbs.) | Safe Working Strength, New Rope (Lbs.) | Weight of Rope, (Lbs. Per Ft.) |
|---|---|---|---|
| ¼ | 700 | 200 | .02 |
| ⅜ | 1450 | 400 | .0417 |
| ½ | 2450 | 700 | .075 |
| ⅝ | 4000 | 1100 | .133 |
| ¾ | 4900 | 1400 | .165 |
| 1 | 8200 | 2300 | .27 |
| 1¼ | 12500 | 3000 | .42 |
| 1½ | 17500 | 5000 | .6 |

Half the value of the loads specified in this table shall be used if the rope has been in service more than 6 months. New rope loses one-third to one-half of its strength in 6 months of ordinary use. Spliced rope has approximately 80% of its original strength. Rope is usually sold by the pound. When ordering rope, where this method is used, convert the footage into pounds by multiplying the required number of feet by the number of pounds per foot as given in Table 1.

*Example:* Required 1,500 feet of ½″. For ½″ diameter, weight is .075. Therefore, $1{,}500 \times .075 = 112.5$ lbs.

**Uses of Manila Rope.** In telephone work, the rope used will depend on the load and other conditions encountered. Manila rope, preferably dry, should be used where there is a possibility of contact with wires carrying current. If the rope is wet or damp the workmen should wear rubber gloves. If other than the standard manila rope is used, examine it carefully to make sure it does not contain a metallic strand. To do this, untwist the strands for a few inches and then untwist the yarns.

**Selecting Size of Rope.** The approximate weight of the load to be handled must be known, before selection of the proper size rope. After determining the load and the rigging that is to be used, select a size of rope whose working strength will not be





exceeded by the weight of the load to be applied. If blocks are necessary, select the simplest rigging to accomplish the work with safety and without loss of time. The size of rope required for use with blocks is determined by the diameter of the sheave groove. A sheave groove with too small a diameter places an excessive bend in the rope, causing the fibers to break. There are proper size ropes for the various size blocks.

**Storing Rope When Not in Use.** New rope shall be left in the original coil until required; it shall be stored in a dry place and in a manner to provide a circulation of air. Used rope shall be stored in the same manner, after it has been coiled or placed on reels. *Do not store new or used rope unless it is completely dry.* To dry rope, hang it up in loose coils on harness hooks or rounded pegs, to permit a free circulation of air around and through the coils. Rope should be dried as soon as practical after it is wet. The drying should be done by placing the rope in the sunshine or in a warm room. Rope, wet or dry, should never be placed over a hot radiator or too near a fire.

**Transporting Rope.** When transporting rope in trucks, it shall be hung on brackets provided for this purpose; the floor shall be kept clear to prevent men from tripping, and to avoid cutting the rope with edged tools or tangling it. Never store or transport rope near a storage battery, as the acid or alkali will seriously injure the rope.

**Inspection Routine.** The man in charge of a construction crew should inspect tackle for faults when it is issued, and at least once during each week of use. He shall make an inspection of the surface of the rope and blocks for any faults that may have developed. Inspection shall be made once each month for the internal condition of the rope.

The person responsible for the tackle shall at all times assume the responsibility of determining that the ropes and blocks are in good condition, and that their appearance indicates neither deterioration nor injury, sufficient to affect their strength.

**Inspection of Manila Rope.** In view of the numerous conditions that may affect the strength and, that only part of the rope may be affected, examination should be made to determine the condition of the rope through its entire length, as explained herein.

If there is any doubt of the safeness of the rope, it shall be exchanged for rope in good condition. The important things to look for on the surface of the rope are as follows:

*Abrasions or Broken Fibers.* Caused by dragging rope over sharp stones, by kinks or crosses in the rope when under tension, cutting with a sharp tool, or by exposure to acids such as the acid used in storage batteries.

*Extremely Soft.* Caused by overstressing rope, wearing out due to normal life of the rope, or by exposure to any cause that will injure the inner fibers.

When inspecting rope for internal faults, the strands should be separated at 3-foot intervals and the fibers inspected for:

*Broken Fibers.* Caused by working rope through sheaves which are too small, or tying to an object which is too small.

*Mildew, Mold, or Fine Powder.* Caused by rope being neither dried nor cleaned properly after being subjected to mud or sand. The fibers of a rope will change color if it is not properly dried before being stored. Fine powder in rope indicates the presence of grit. To remove grit, the rope should be whipped up and down on a hard surfaced road, after being thoroughly dried.

**Inspection of Blocks.** Blocks should be inspected to determine their condition as suggested in the following:

1. Bent, broken, or cracked shell
2. Cracked or broken sheave
3. Cracked or broken becket
4. Cracked or broken straps
5. Bent hook
6. Cotter pin missing
7. Roller bushing not functioning

If any of the above conditions exist and there is any doubt as to the safety of the block, it shall be exchanged for one in good condition.

**Maintaining Blocks in Field.** Keep blocks free of oil and dirt. The sheaves of the standard blocks are roller bushed and operate better without oil which tends to collect oil and grit, thereby causing the rollers to bind. If the sheaves do not function properly, remove the sheave as outlined in the following material and remove the dirt by tapping the sides of the sheave lightly.





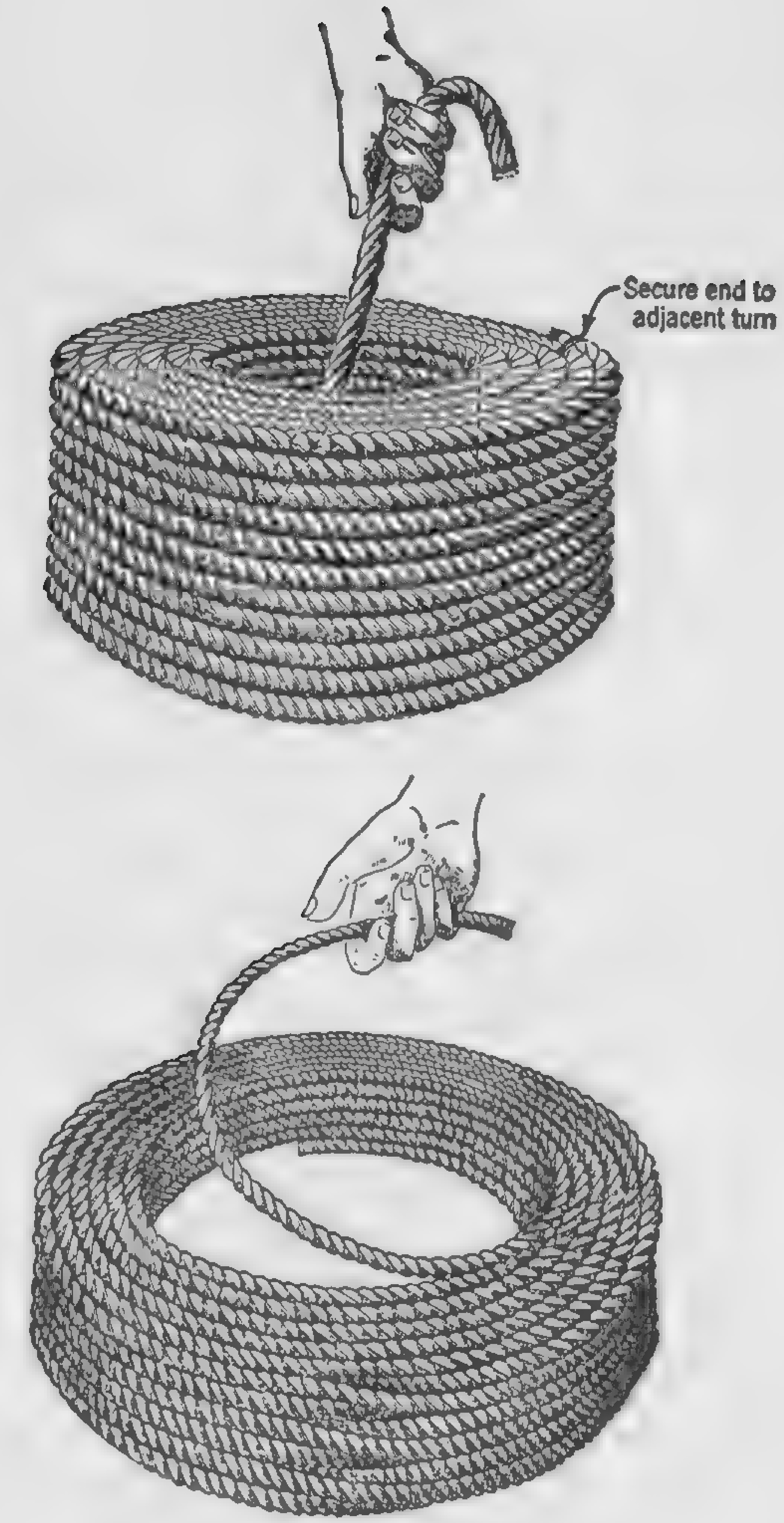



Fig. 1

If the hook of a block has started to open, exchange the block, or, if a spare hook is available, replace the hook. This is done by removing the cotter pin from the sheave pin with pliers. It may sometimes be necessary to oil the pin with kerosene and drive it out with a hammer. After removing the cotter pin, pull out the sheave pin, being very careful not to drop the sheave, which would break or scar the edges of the sheave. Pull hook straps out and replace the new hook in position.

**Coiling and Uncoiling Rope.** When used rope is not placed on reels, lay out a turn of the desired size and continue the turns in a clockwise direction.

In uncoiling used rope, turn the coil over and draw the end first laid down, from the inverted coil. Be careful not to select the wrong end, if the coil has been tangled or upset.

Remove new rope from coil as explained here; this method retains the rope in its proper form and prevents kinks. See Fig. 1.

1. Remove the binding material and secure outside end of rope to an adjacent coil.

2. Lay the coil on the flat side with the inside end nearest the floor.

3. Reach down through the coil, grasp the free end of rope, and draw out through the top of coil.

**Cutting Manila Rope.** Before cutting rope, wrap several turns of friction tape around the rope on each side of cut, and cut rope with a sharp tool. If it is desired to keep the ends from permanently untwisting, serve or whip them with a strong twine or place a crown splice in the ends.

## COMMON ROPE SPLICES

**Serving Splice (Whipping).** The operations required to serve the ends of a rope are as follows: See Fig. 2 at (*a*).

1. Unlay one strand of the rope back a little more than one turn, to a point where the serving is to begin. Under this strand lay the twine, leaving the end marked *1*, 8″ to 10″ long as shown in the upper left of Fig. 2 at *A*. Then relay the strand into the rope, keeping it tightly twisted and held firmly in place.

2. Let the short end of the twine *1* hang down the rope. Wind the long end of the rope, marked *2*, around the rope, just above the short end as shown in 2-*B*.

3. Lay the end of twine marked *1* along the rope towards its end and there bend it back, thus forming the open bight *3*, as shown in 2-*C*, which can be pulled in under the serving when tucking the ends.

4. Lay the sides of the bight *3* in a groove of the rope. Wind the long end of the twine *2* around the rope and the





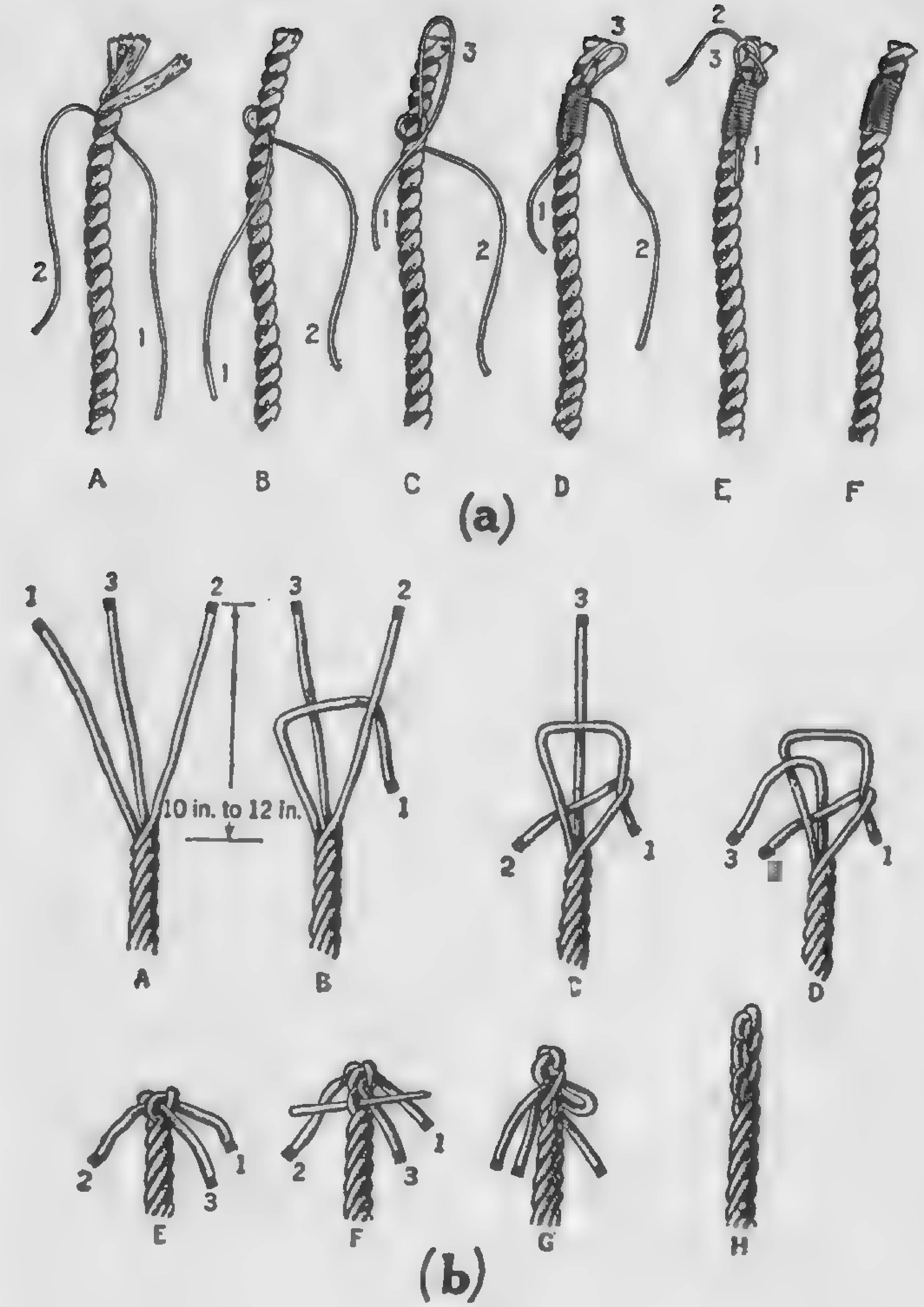



Fig. 2

doubled twine, being careful to pull it up tightly and to leave no open spaces between the turns as shown in 2-*D*.

5. Continue winding as far as desired, then pass the long end *2* of the twine through the bight *3*, as shown in 2-*E*, and pull the long end up firmly. By pulling on the free end *1*, of the bight *3*, draw the long end of the twine *2*, downward underneath the serving, to about the center, *not all the way through*.

6. Finish the serving by cutting off the two protruding ends

of the twine as closely as possible. Cut off excess rope as shown in 2-*F*.

**Crown Splice.** See Fig. 2 at (*b*).

1. Unlay the rope for 10″ to 12″ and hold it in one hand with the loose ends up as shown at left center *A* of Fig. 2.

2. Take strand *1* on the left and lay it across the end of the rope between the other two strands as shown in 2-*B*.

3. Take strand *2* back and down over strand *1* as shown in 2-*C*.

4. Take strand *3* across *2* through bight in *1* as shown in 2-*D*.

5. Pull all ends tight as shown in 2-*E*.

6. Continue tucking each successive strand over the nearest strand and under the next strand of the main rope as shown in 2-*F*.

7. Tuck until about four complete operations are made.

8. Roll between two surfaces under pressure, as between foot and floor, to smooth out splice, then cut off surplus ends flush with the outside strands. The completed splice is shown in 2-*H*.

**Eye Splice.** The eye splice is used to form a permanent loop or eye, in the end of the rope. This splice has 90% of the strength of a straight rope. When heavy wear will take place on the inside of the eye, it is advisable to splice an oval thimble in the eye. An eye splice is illustrated at (a) in Fig. 3.

1. Untwist the strands of the rope for a length of 10″ to 16″. Throw a bight into the rope of a size to correspond with the size of the eye required. Select as strand *1* the strand that is on top of the rope and between the other two loose strands as in 3-*A*.

2. Raise a strand on the top of the main rope and tuck *1* under it at right angles, as in 3-*B*, pulling it down securely. Raise the adjoining strand in the main rope and tuck *2* under it as in 3-*B*. Raise the remaining strand in the main rope and tuck *3* through.

3. When all the ends have been tucked through for the first time, pull them down tight as in 3-*C*. Proceed to interweave the strands as in a short splice.

4. Roll the splice between two flat surfaces under pressure, as between foot and floor, and trim off surplus ends flush with the outside strands. The completed splice is shown in 3-*D*.





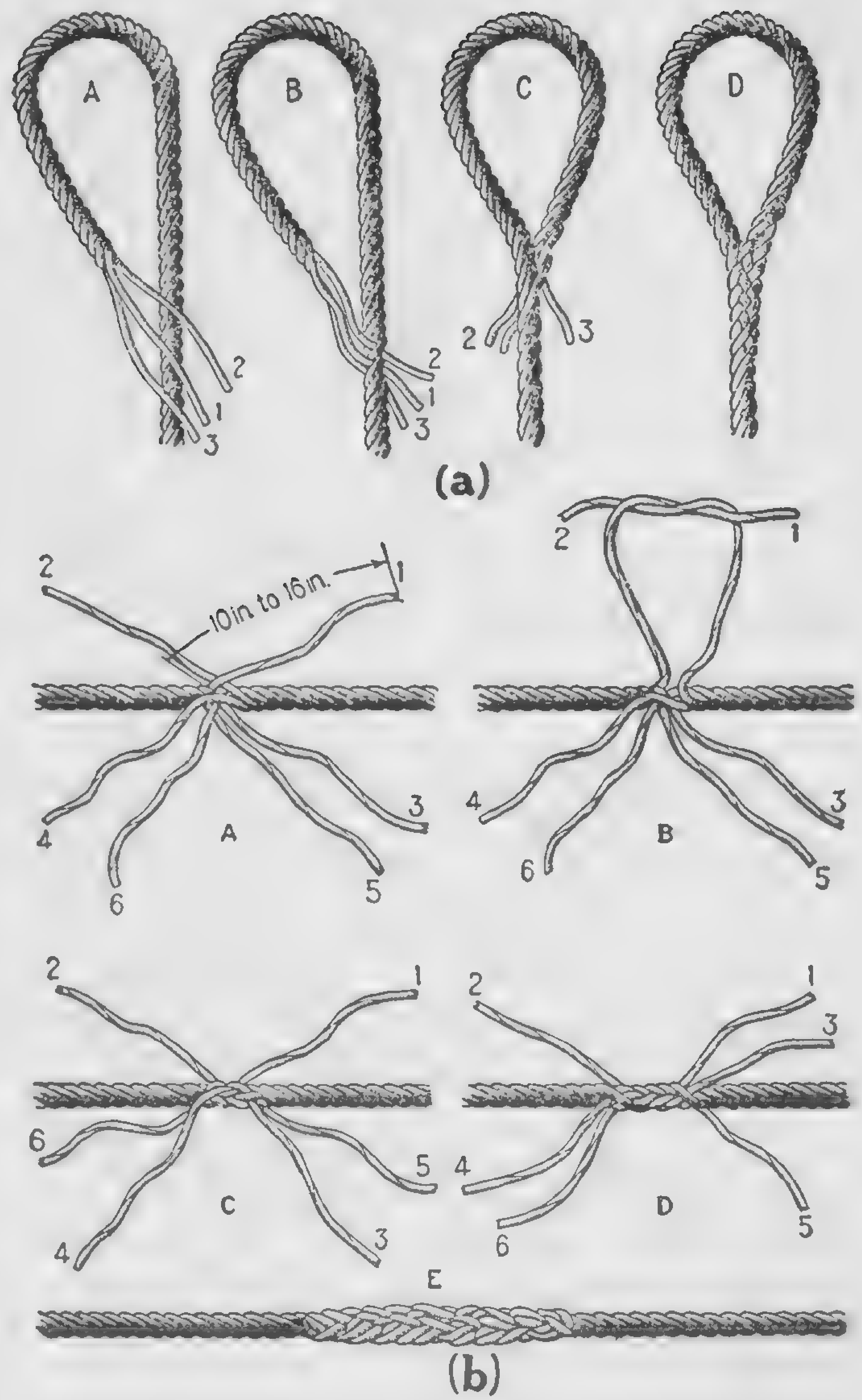



Fig. 3

**Short Straight Splice.** Short straight splice is used to unite the ends of rope by interweaving strands, and when properly made it has 80% of the strength of the rope. See Fig. 3 at (b).

1. Untwist the strands at one end of each rope for a length of 10″ to 16″. Butt the ends of the rope tightly together as in 3-*A* laying the strands of each rope alternately between the strands of the other rope; that is, strand *1* is between *2* and *4*; strand *3* is between *4* and *6*, and strand *5* is between *2* and *6*. This process is called *locking the strand*.

2. Tie each strand of one rope to the corresponding strand of the other rope with a regular overhand knot as *1* and *2*, of 3-*B*. Complete tying *3* to *4*, and *5* to *6*, in a similar manner.

3. Pull all knots down tight as in 3-*C*.

4. Carry each end over the adjacent strand of the rope and tuck it under the next strand. Start with and proceed to strand *6*, in progressive order. This will produce an arrangement as in 3-*D*. Repeat this operation until the total length of the interweaving strands extends through a distance of 4″, for one-quarter inch

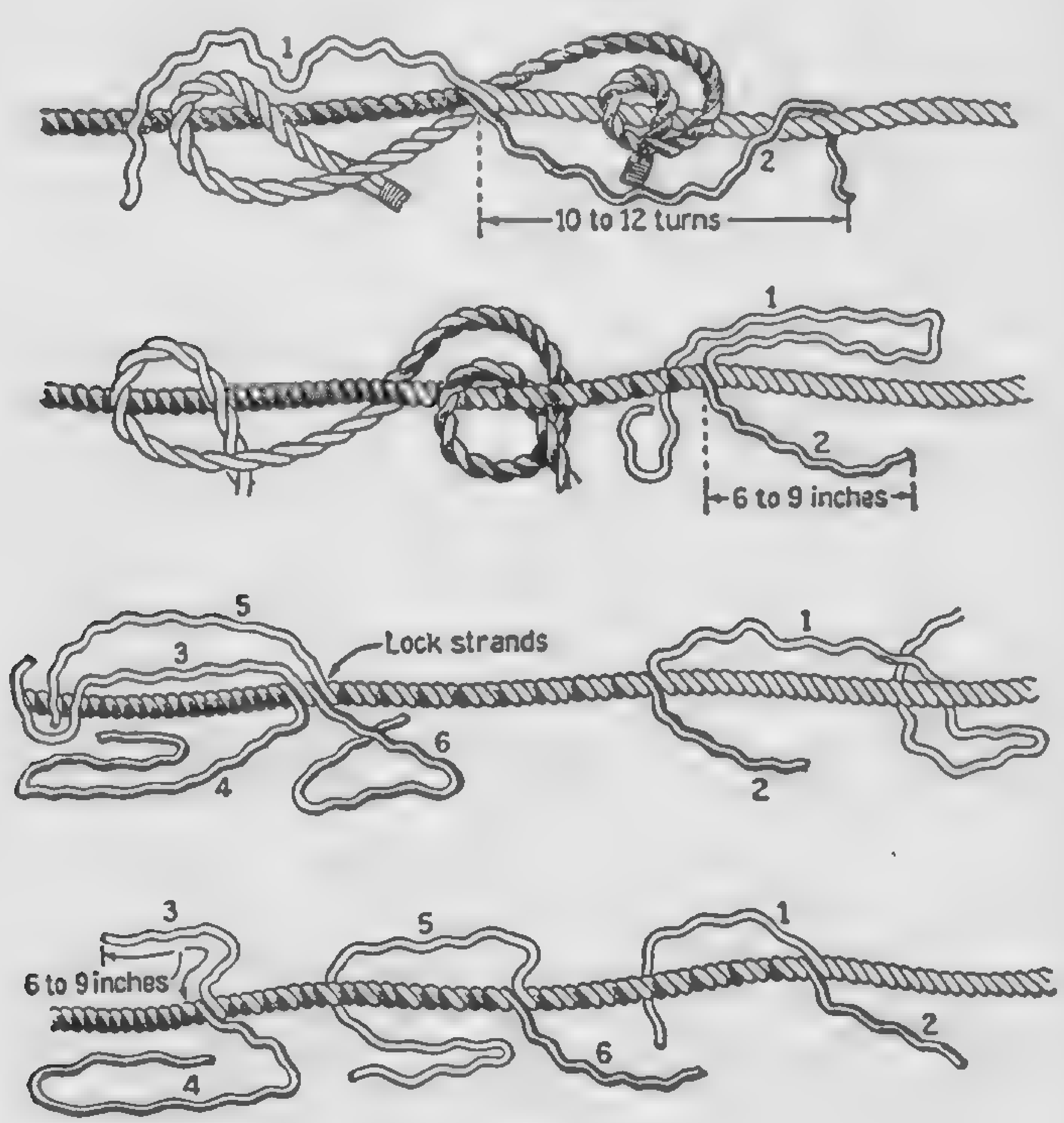



Fig. 4





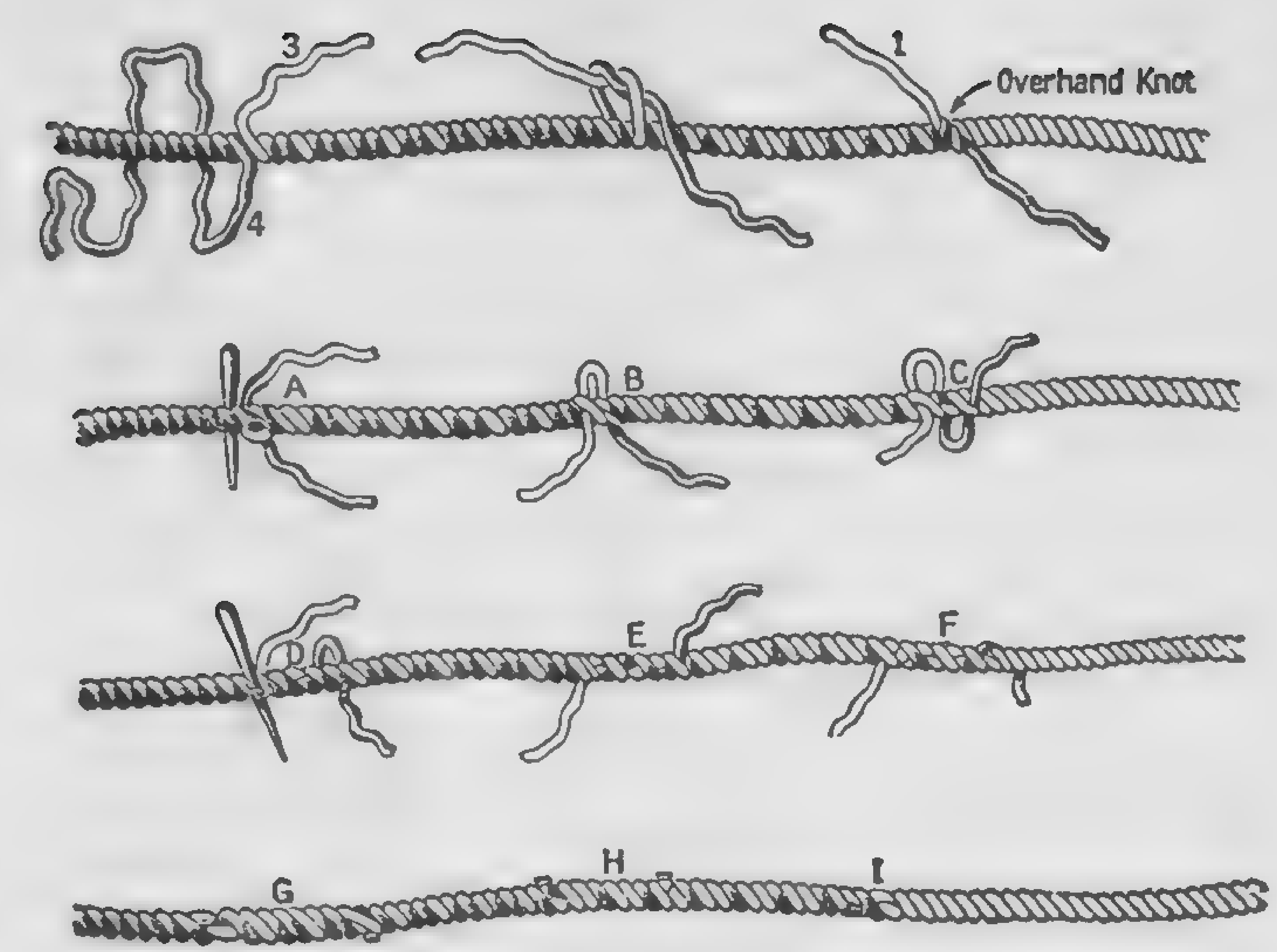



Fig. 5

rope, and add an additional tuck for each next largest standard size rope.

5. Roll splice between two flat surfaces under pressure, as between foot and floor, and trim off the surplus ends flush with the outside strands. The completed splice is shown in 3-*E*.

**Long Straight Splice.** The long straight splice is used to unite the ends of rope required for passing over sheaves, by interweaving strands, and when properly made it has 90% of the strength of the rope and therefore it is stronger than the short straight splice. Figs. 4 and 5 illustrate, in sequence, the steps in making the long straight splice. This splice has the advantages of being stronger than the short straight splice and smaller than the short straight splice, thereby allowing it to pass through the sheaves of a block.

1. Unlay only one strand of each rope for 10 or 12 turns. Lock and draw ends of the rope tightly together, having the single strands *1* and *2* side by side, as illustrated in Fig. 4.

2. Taking care not to let the ends of the ropes separate, unlay strand *1* from its rope one turn, and follow it with strand *2*. Keep *2* twisted up tightly and pulled down firmly into its place. Continue this procedure until only 6″ to 9″ of strand *2* is left out, depending on the size of the rope.

3. Untwist the two pairs of strands left at the center and lock them as shown in Fig. 4. Strand *3* between strands *4* and *6*, and strand *6* between strands *3* and *5*. Unlay toward the left; strand *4*; and follow it with strand *3*, as was done toward the right with strands *1* and *2*. *Note: Do not unlay strand 6 instead of 4 and follow it with 3.*

4. Continue until strand *3* is only 6″ to 9″ long. The breaks in the strand are now separated as shown in Fig. 4.

5. Each pair of strands is tied together now, and the end of each strand tucked. Cut all strands the length of the shortest, that is, 6″ to 9″ long. Arrange each pair so that the strand from the left is in front of the strand from the right; or, in other words, arrange the strands so that they cannot untwist from the rope without first uncrossing. Tie each pair of strands together with an overhand knot and pull down tightly into rope as shown in Fig. 5.

6. Tuck each strand as shown in Fig. 5.

7. Tuck each strand twice more, tapering the ends if desired, and cut the end ½″ long.

8. With a round stick, pound down each part of the splice and roll it between two flat surfaces under pressure, as between foot and floor. The completed splice is shown in Fig. 5.

## COMMON KNOTS, BENDS, AND HITCHES USED IN TELEPHONE WORK

The strength of manila rope containing a knot is reduced about 60%, as the bend in the rope places most of the strain on the outside fibers.

**Figure-Eight Knot.** This knot is used to prevent the end of a fall line from running through the blocks. See Fig. 6 at (a). Throw a turn into the rope leaving sufficient end to complete the knot, then pass the end around the rope and through the bight. Draw all parts down tight.

**Block Becket Bend.** This knot is used when attaching a rope to the eye of a guy rod or to the becket of a block, where a temporary connection is desired. See Fig. 6 at (b).

1. Pass the rope around the thimble on the becket of a block as shown in 6-*A*.





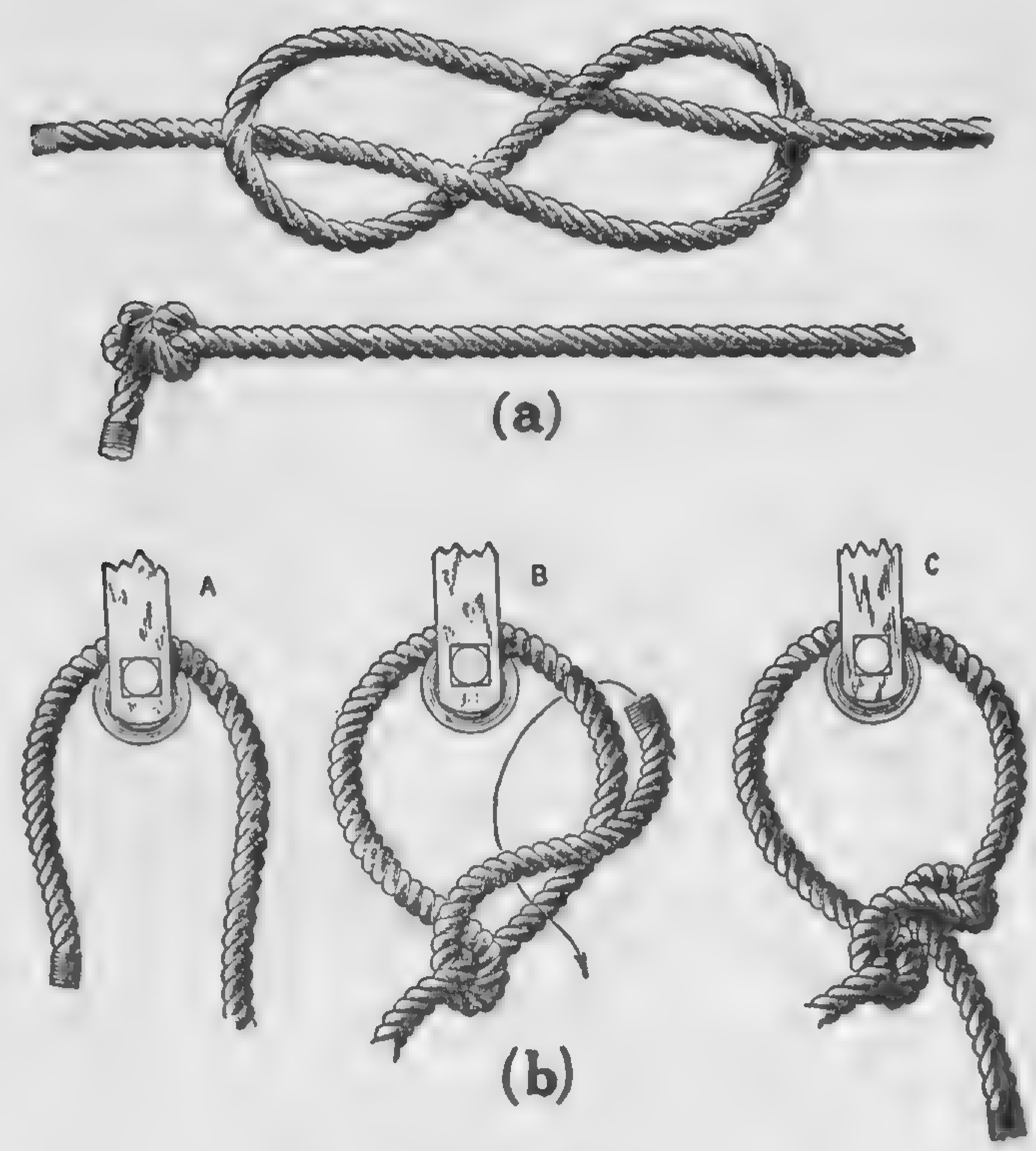



Fig. 6

2. Take a turn around the standing part outside of the bight as illustrated in 6-*B*.

3. Take a second turn around the standing part through the bight, forming two half-hitches in reverse as shown in 6-*C*.

**Square Knot.** This knot is used in uniting the ends of the same size ropes, that may be placed under strain. A square knot, joining two ropes of unequal size is very apt to slip. Fig. 7 illustrates a square knot.

1. Cross the ends of the rope, placing the right under the left as at *A* in Fig. 7.

2. Bend each rope back on itself as shown in 7-*B*.

3. Wrap end marked *1* around the end marked *2*, away from you as shown in 7-*C*.

4. Pull all parts down tight. The completed knot is shown in 7-*D*.

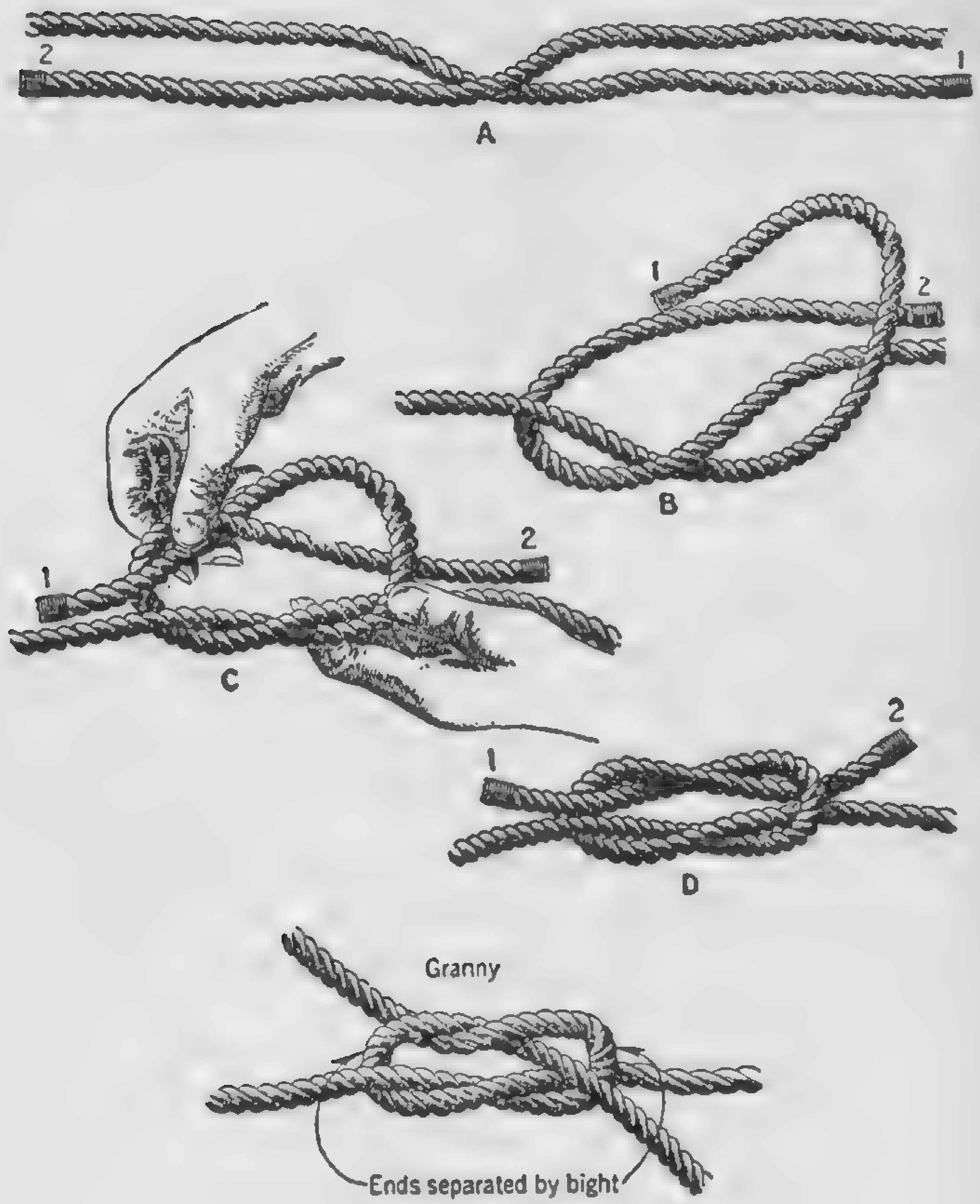



Fig. 7

A *granny knot* is shown in Fig. 7, so that it may be readily identified and avoided.

**Bowline Knots, General.** The bowline knots are used in making hitches of all types and are formed in various ways, depending upon the conditions encountered. It is a tie of universal use and is the best known method for forming a bight that will not slip under tension and is easily untied.

**Single Bowline at End of Rope, Not Attached to Object.** This knot is used for attaching a rope to the hook of a block or joining the ends of ropes of different sizes. See Fig. 8.

1. Grasp the standing part of the rope with the left hand, at a point where the turn *T* is desired. This position is determined





from the size of the bight *Y*, required. Hold the free end in the right hand.

2. Move the right hand forward and lay the free end across the standing part of the rope, above the left hand, with sufficient end to complete the subsequent turns. Hold the right hand stationary and bring the left hand upward and forward as indicated by the arrow *1*.

3. Just as the left hand is passing the right, turn the right

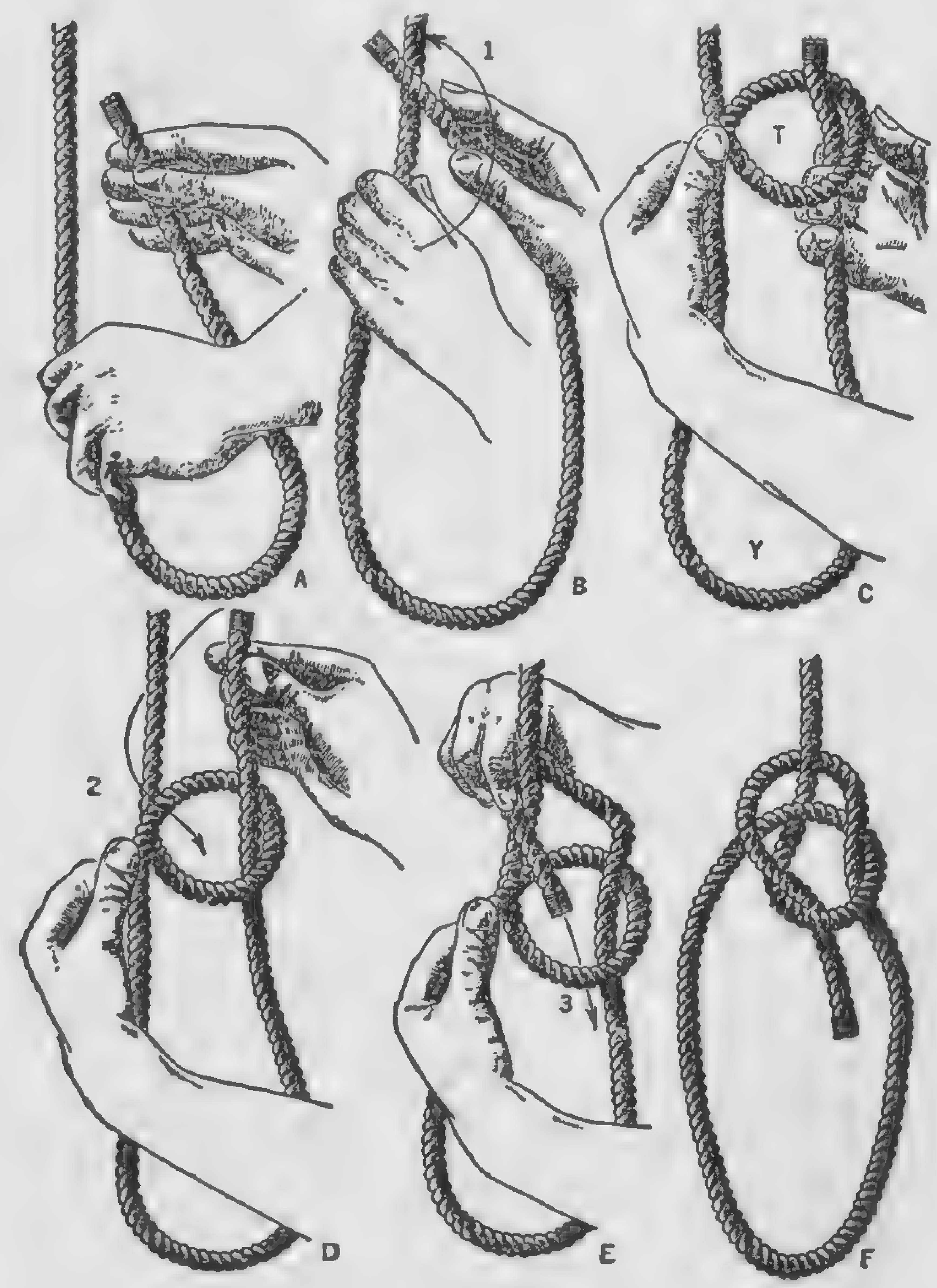



Fig. 8

hand palm up, which will result in the formation of a loop in the standing part of the rope, with the end of the rope projecting up through it.

4. Grasp the free end with the right hand and move it forward.

5. Pass the free end around and behind the standing part of the rope from right to left, as indicated by the arrow *2*, then pass the free end forward and down into the turn again, from above, as indicated by the arrow *3*.

6. Draw all parts down tight. The completed knot is shown at *F* in Fig. 8.

**Single Intermediate Bowline.** This knot is used to attach the rope to the hook of a block, where the end of the rope is not readily available. See Fig. 9.

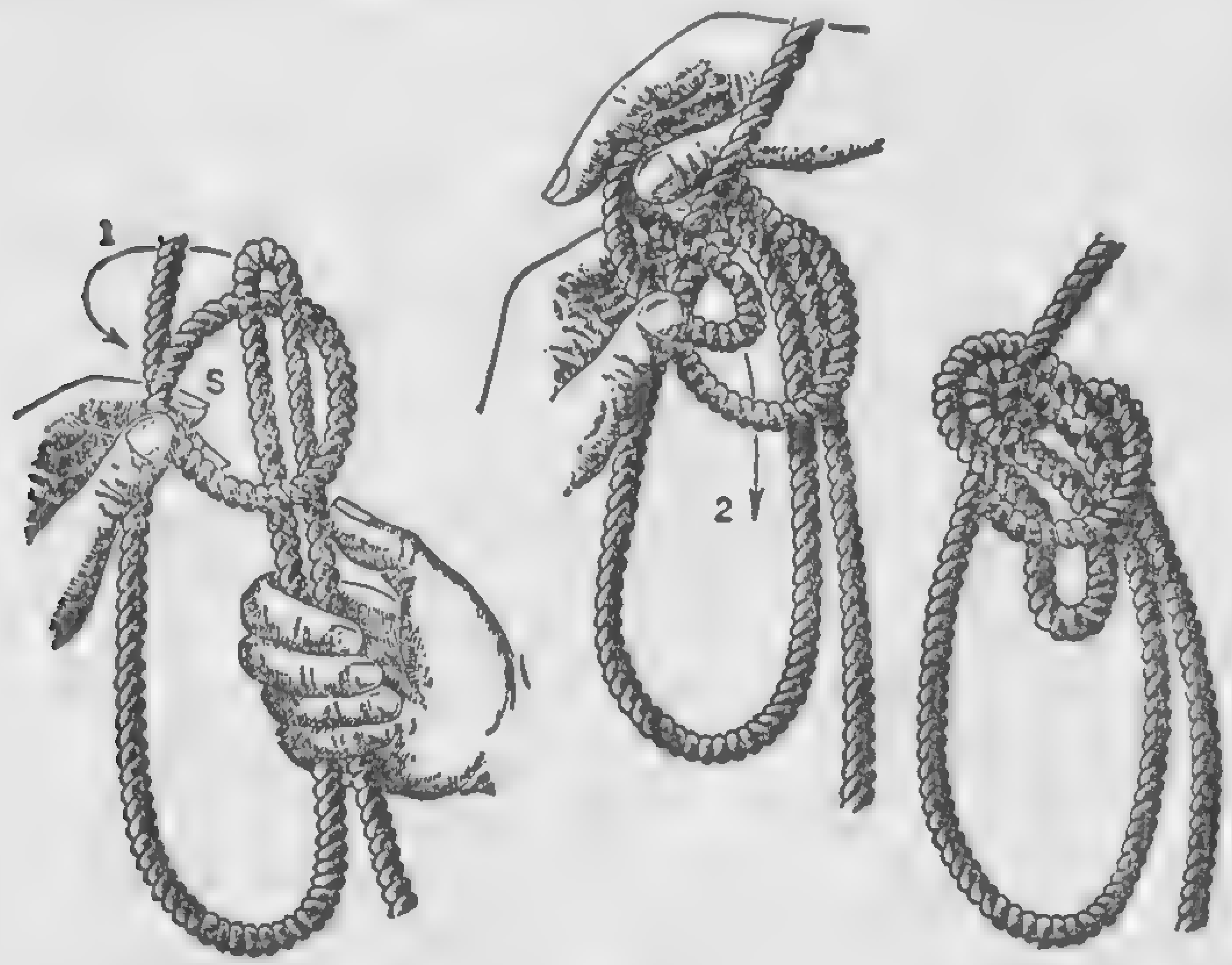



Fig. 9

1. The operations required in making this knot are identical with the single bowline, not attached to an object, with one exception; that is, in step *D* in Fig. 8, the part with which the knot is completed is not a free end but a part of the rope doubled back in a bight.

**Single Bowline, at End of Rope, Attached to Object.** This knot is for tying a bowline through a ring or eye. See Fig. 10.

1. Throw a turn into the rope, leaving sufficient end to com-





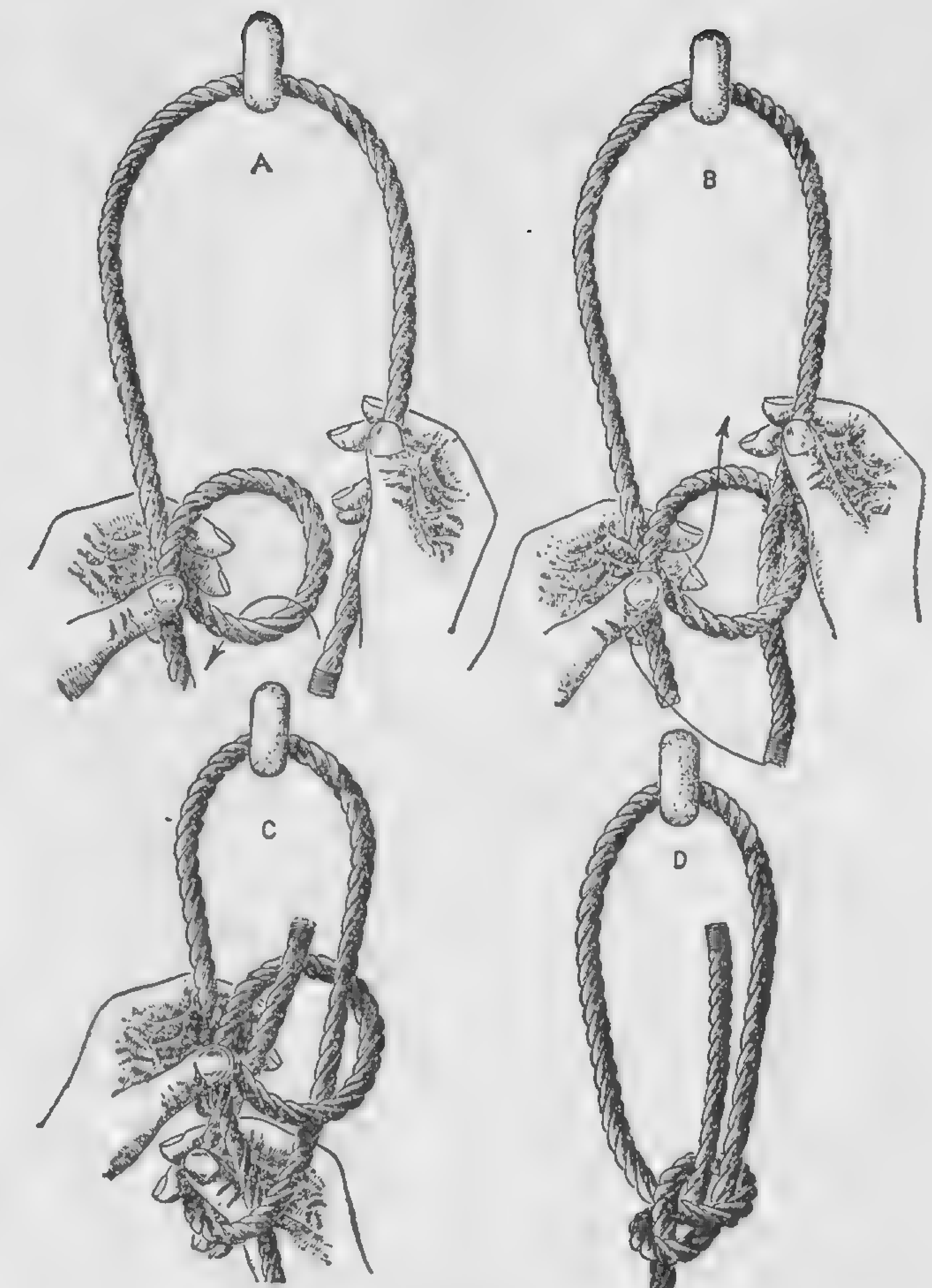



Fig. 10

plete the knot, then pass the free end through the eye or around the object, holding the standing part with the turn in the left hand as shown in 10-*A*.

2. Pass the free end through the turn in the standing part of the rope as illustrated in 10-*B*.

3. Bring the free end from right to left, over the standing part of the rope and turn it under, passing the end through the turn as shown in 10-*C*.

4. Draw all parts down tight. The completed knot is shown at *D* in Fig. 10.

**Double Bowline.** This knot is used in tying at intermediate points, and allows two ropes to pass through the eye or point of strain, thereby doubling the strength at the point of greatest stress. See Fig. 11.

1. The operations required to make this knot are identical

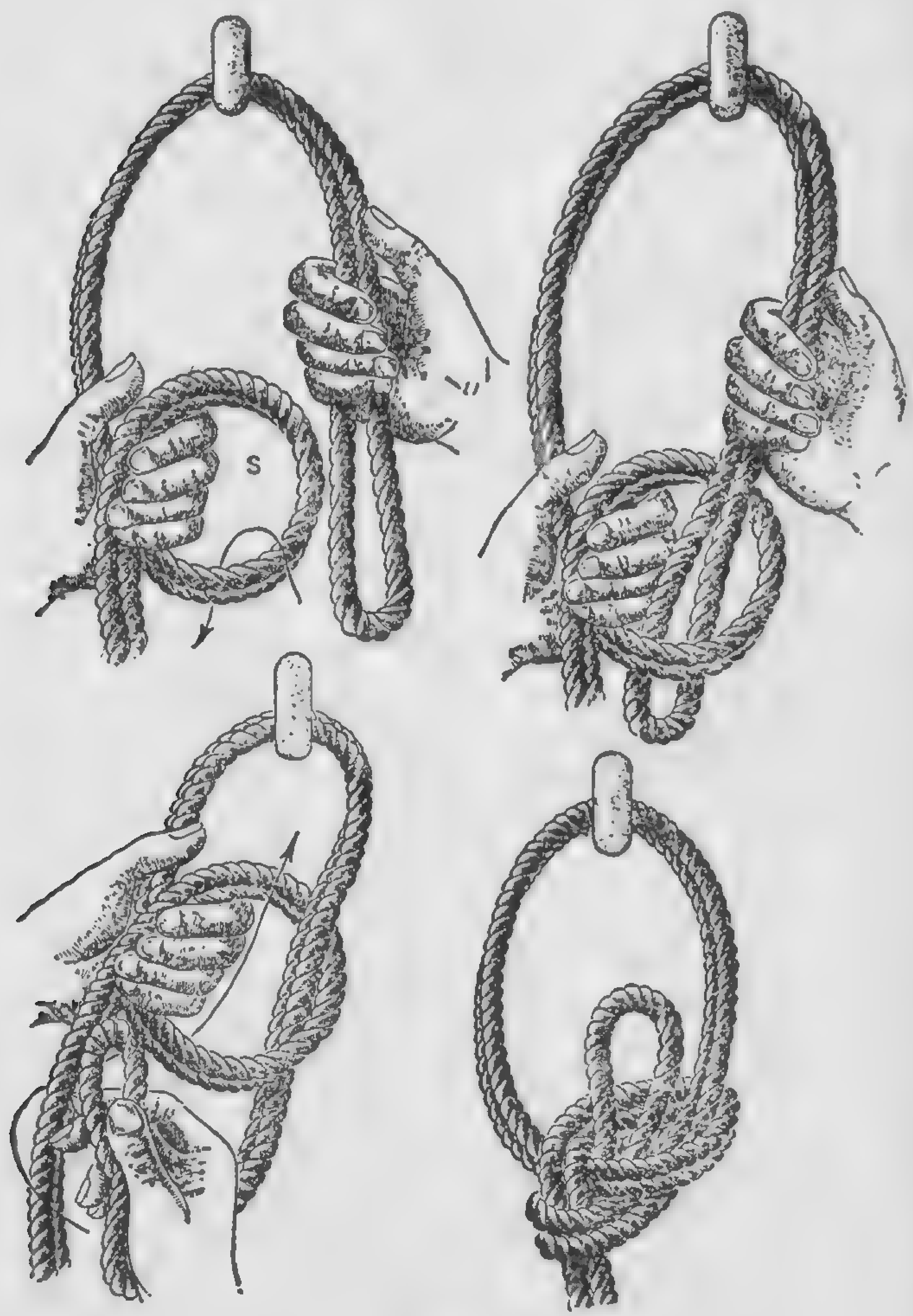



Fig. 11





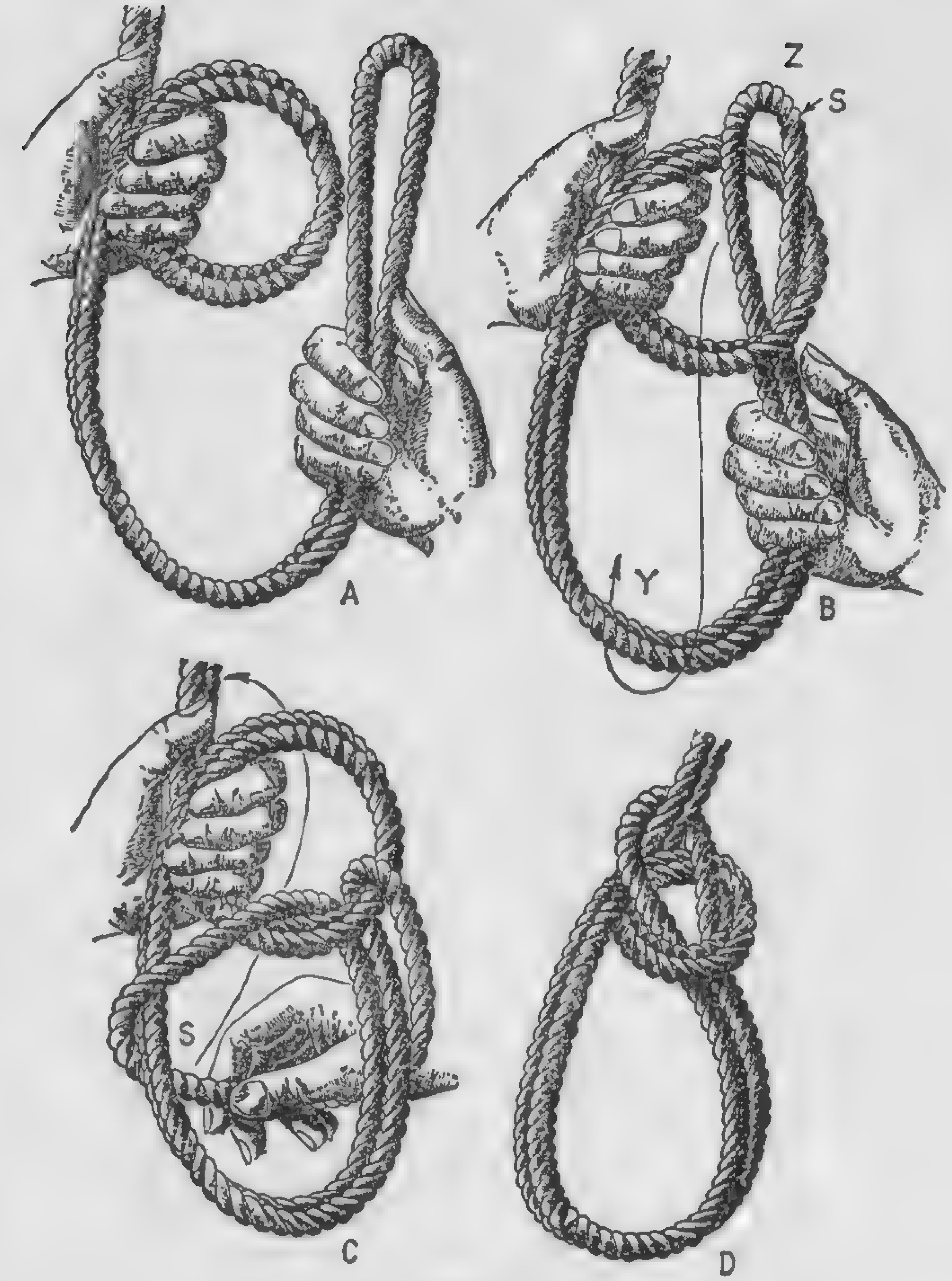



Fig. 12

with the operations of the single bowline, at the end of a rope, attached to an object.

**Double Bowline on a Bight.** This knot is used as a semi-permanent eye in the middle or end of a rope, to engage a hook, clevis, or some other similar fastening. This knot allows two ropes to pass through the fastening. See Fig. 12.

1. Double the rope and throw a turn into it leaving sufficient end to complete the knot as shown in 12-*A*.

2. Pass the end through the turn, as explained for a single

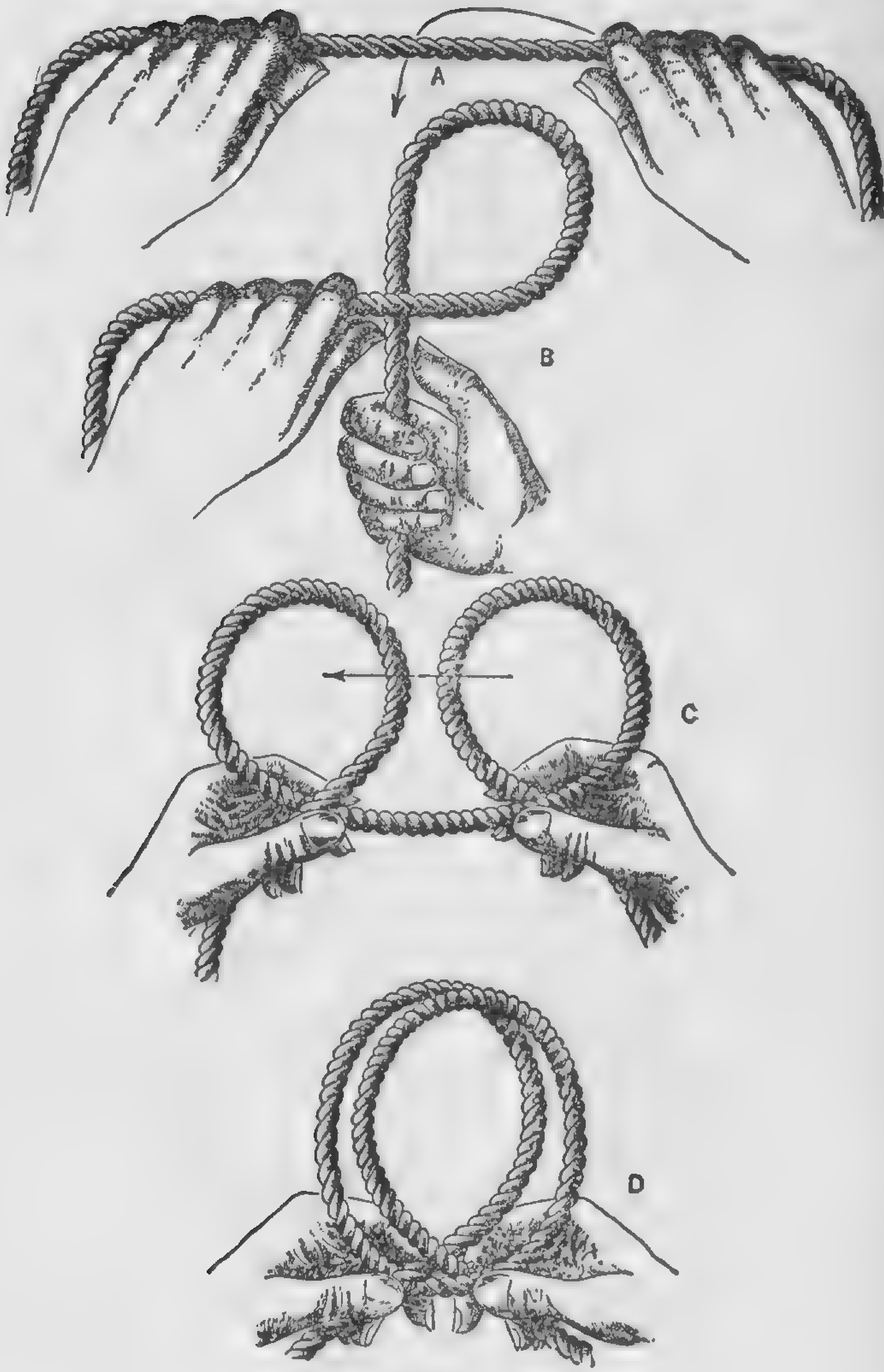



Fig. 13

type bowline, until the position shown at *Z* is reached as shown in 12-*B*.

3. Turn the bight *S*, down over the front and then up in back of turn *Y* as shown in 12-*C*.

4. Pull all parts down tight. The completed knot is shown in 12-*D*.





**Clove Hitch.** The clove hitch is used in attaching tools and materials to a hand line. It may also be used in guying gin poles, when the tension is equally divided along the guy ropes in opposite directions. This hitch will stand a stress in either direction when properly set. It is quickly made and easily undone. The clove hitch is composed of two half-hitches made either at the end of a rope or in the middle without access to the ends. It can be made in a number of ways, three of which are explained here and illustrated in Figs. 13, 14, and 15.

Method of making a clove hitch to pass over low objects, such as a stub pole or stakes. See Fig. 13.

1. Hold the rope as shown in 13-*A*.

2. Twist the rope held in the right hand to form a loop, shown in 13-*B*.

3. Hold this loop with the left hand and throw a second loop with the right hand in the same manner, shown in 13-*C*.

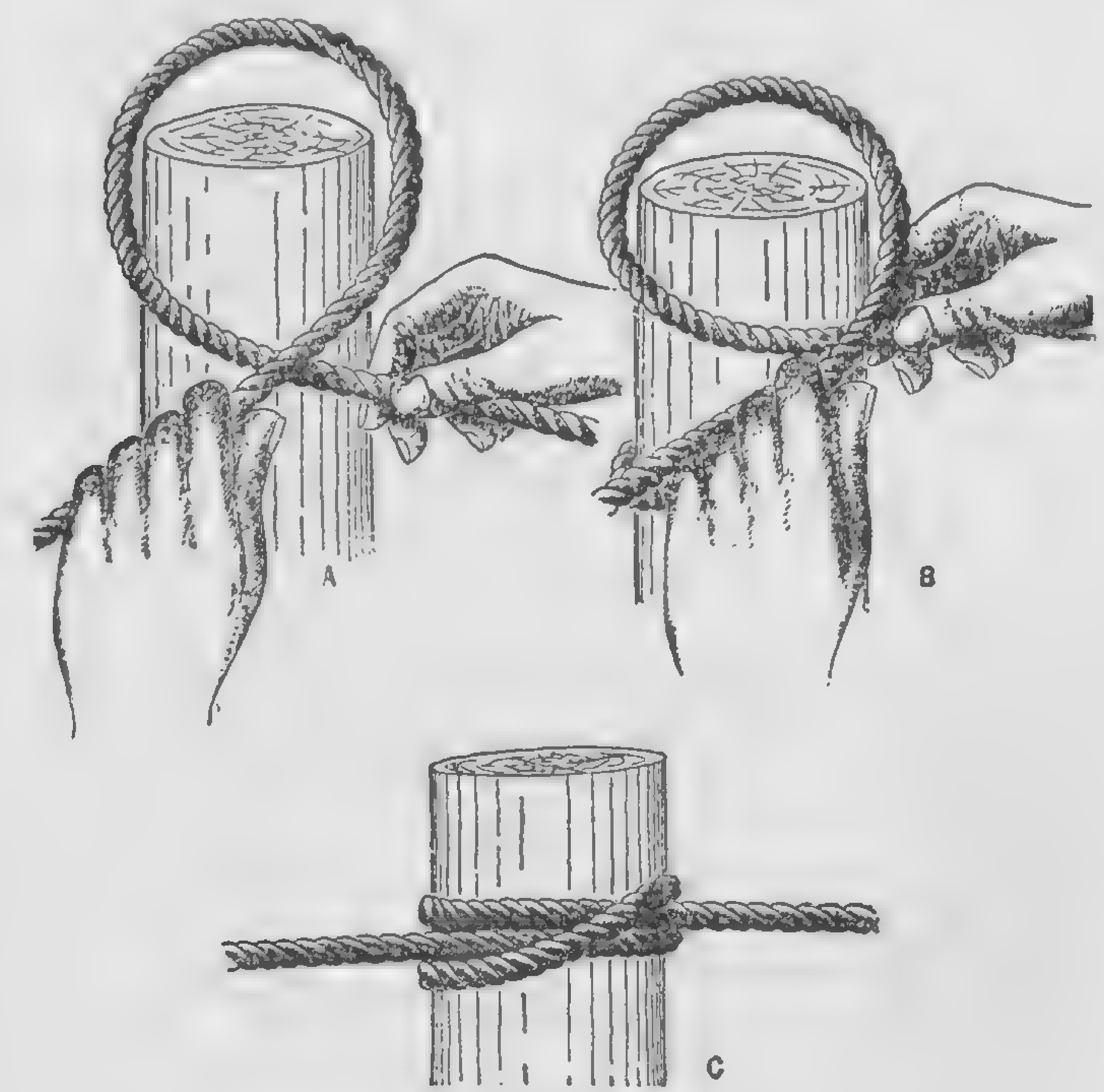



Fig. 14

4. Bring the loops together as shown in 13-*D*, then place over the object and pull taut.

Method of making a clove hitch when there is a pull on the rope. See Fig. 14.

1. Hold the strain on the rope with the left hand and twist

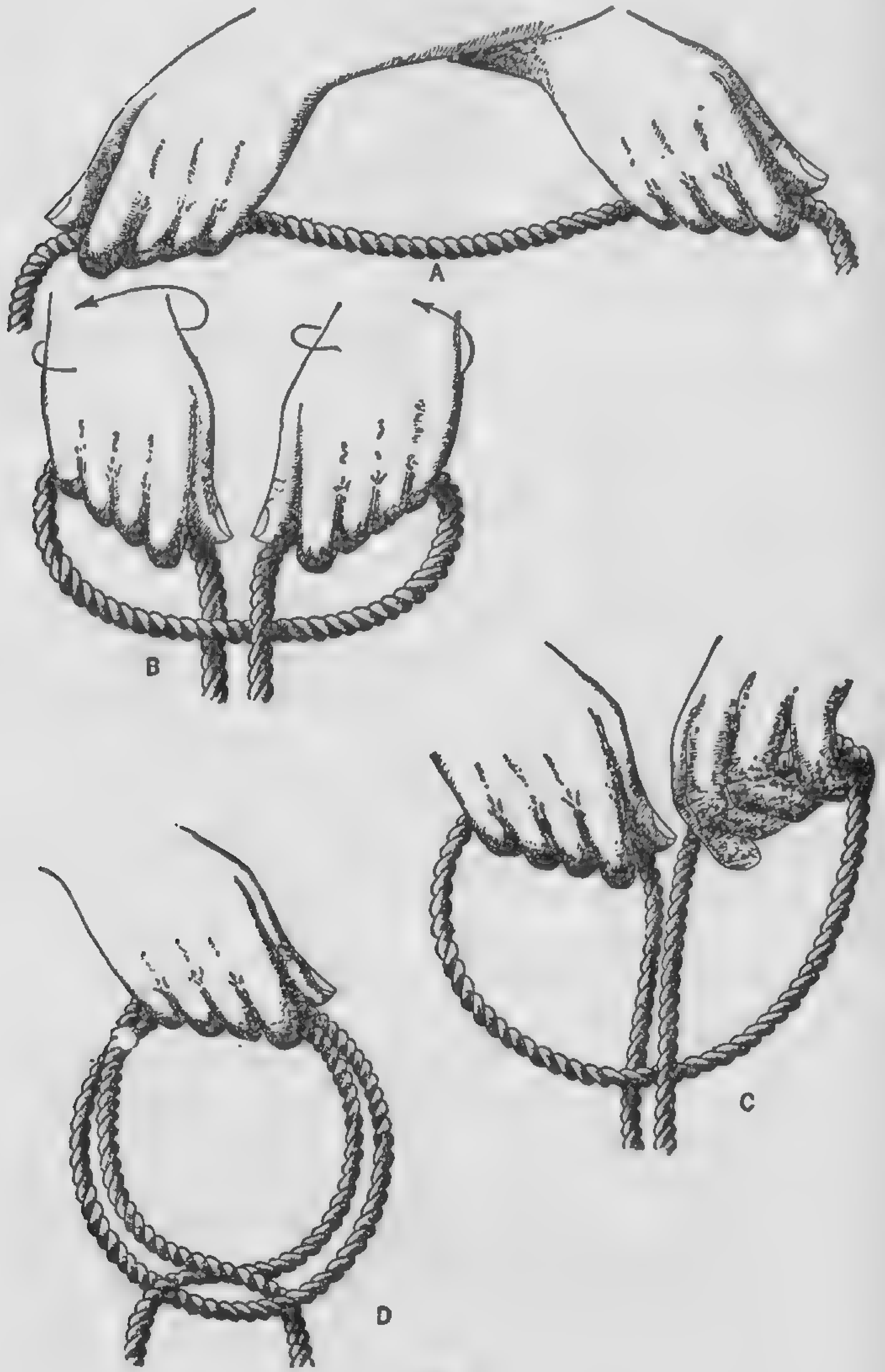



Fig. 15





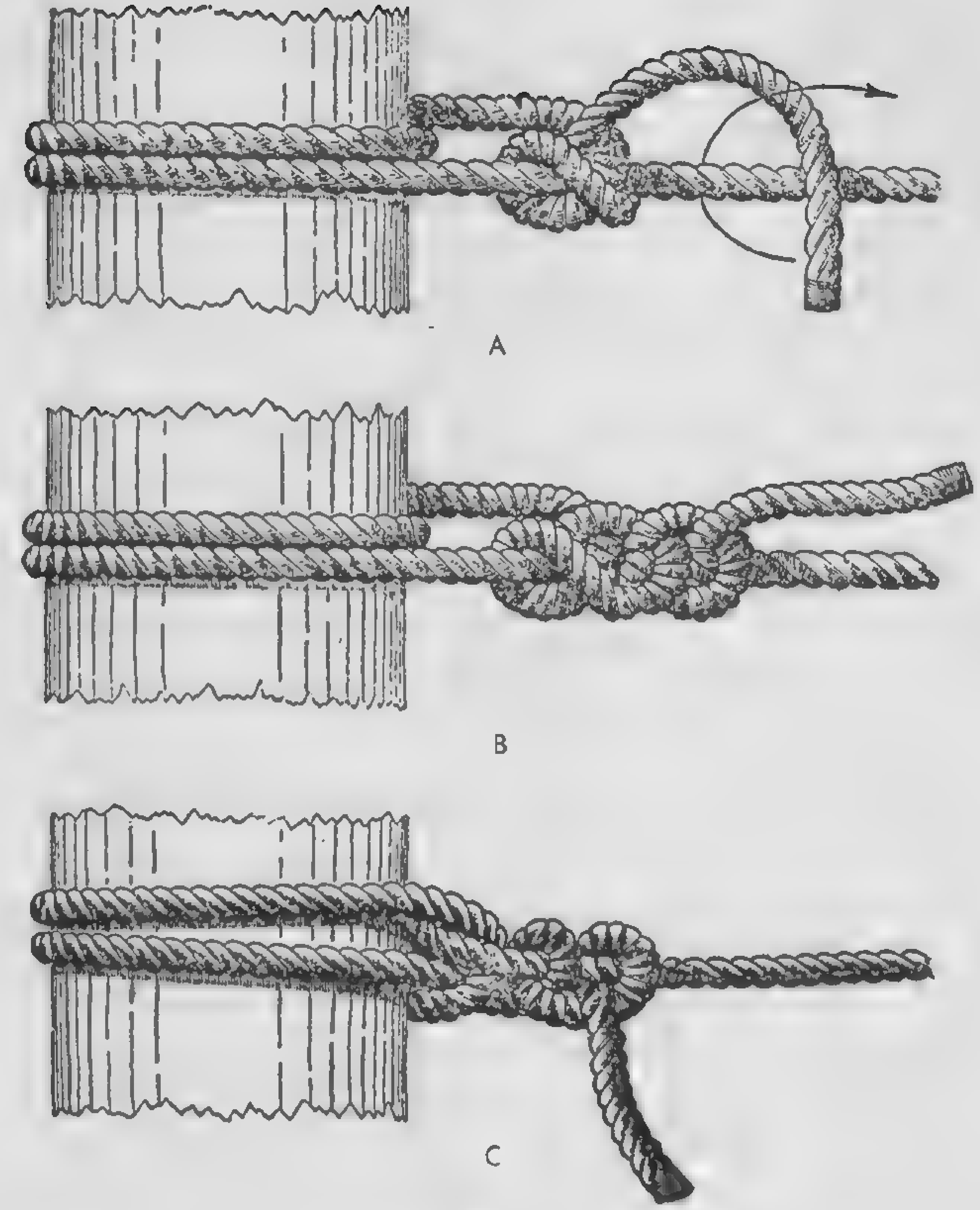



Fig. 16

the rope to the right, with the right hand, to form a loop in the rope, and then roll the loop over the top of the post. Shown in 14-*A*.

2. Move the left hand up beyond the loop, hold the rope there and with the right hand form a second loop, roll it in place and pull taut. See 14-*B*.

3. The completed knot, in place, is shown in 14-*C*.

The quickest method of making a clove hitch is shown in Fig. 15.

1. Cross the arms in front of the body, with the left arm outside the right and pick up the rope as shown in 15-*A*.

2. Without twisting the wrists, uncross the arms; shown in 15-*B*.

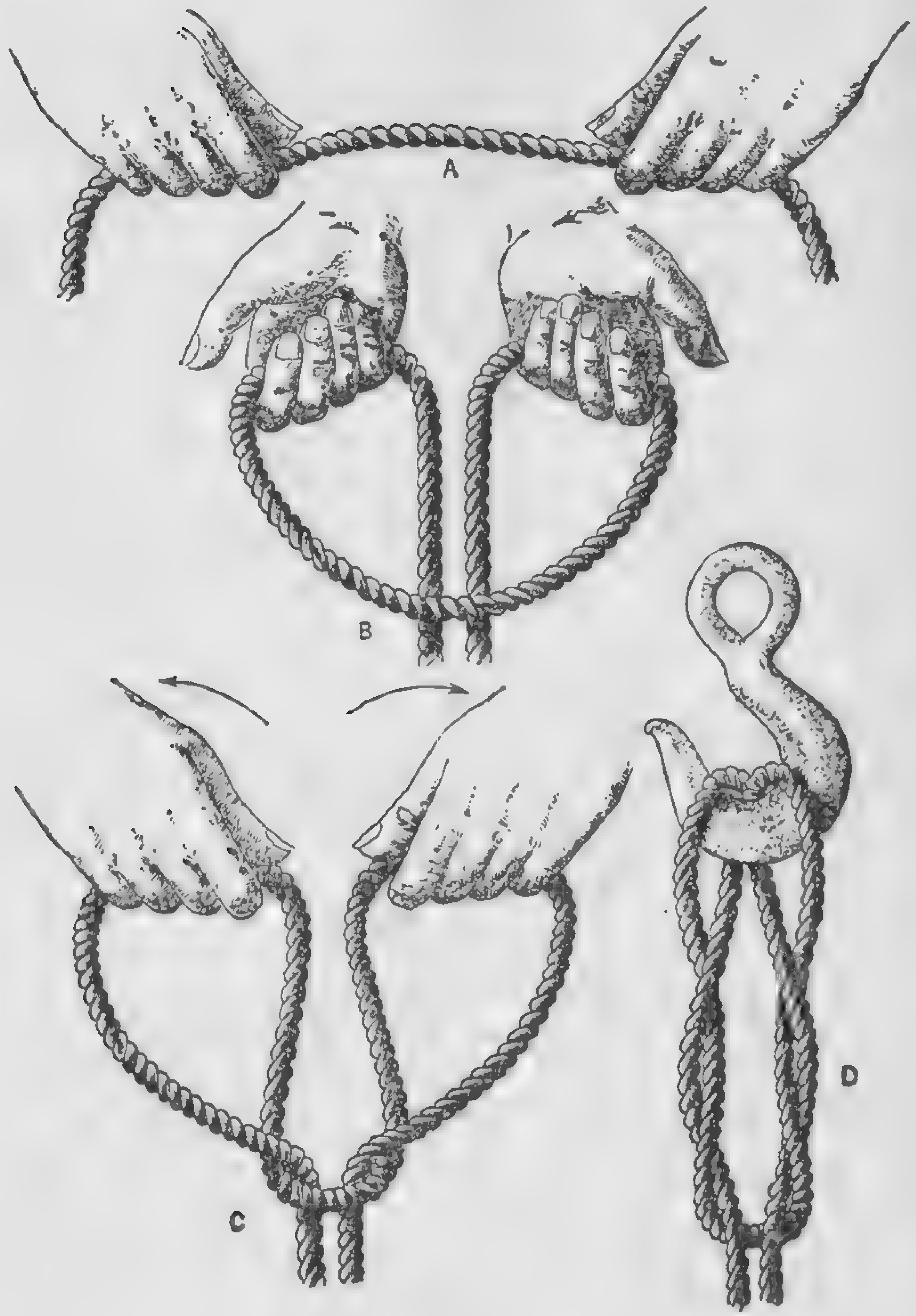



Fig. 17

3. Now rotate both hands to the right, as indicated by the arrows around the wrists, shown in 15-*B*, and put the knuckles of the left hand into the palm of the right hand.

4. Slip the loop from the left hand into the right hand, and the hitch is ready to pass over the object. Shown in 15-*D*.

**Snubbing Hitch.** This knot is used for securing temporary guys to poles and trees. See Fig. 16.

1. Pass the rope around the pole or object twice, then turn





the free end around the standing part inside the bight. Shown in 16-*A*.

2. Take another turn inside the bight as shown in 16-*A*.

3. Complete the hitch with two half-hitches as shown in 16-*B* and 16-*C*.

**Catspaw.** This knot is used in attaching a rope to the hook of a block. It provides a double rope over the hook of the block and permits a load to be carried on either end of the rope. See Fig. 17.

1. Grasp the rope as shown in 17-*A*.

2. Drop rope between the hands to form a bight, then twist the hands, thus forming two loops as shown in 17-*B*.

3. Twist each loop a half turn in the direction indicated by the arrows in 17-*C*.

4. Twist each loop another half turn and hang loop on the hook. The completed hitch is shown in 17-*D*.

**Platform Guy Knot.** This knot is used in securing the ropes

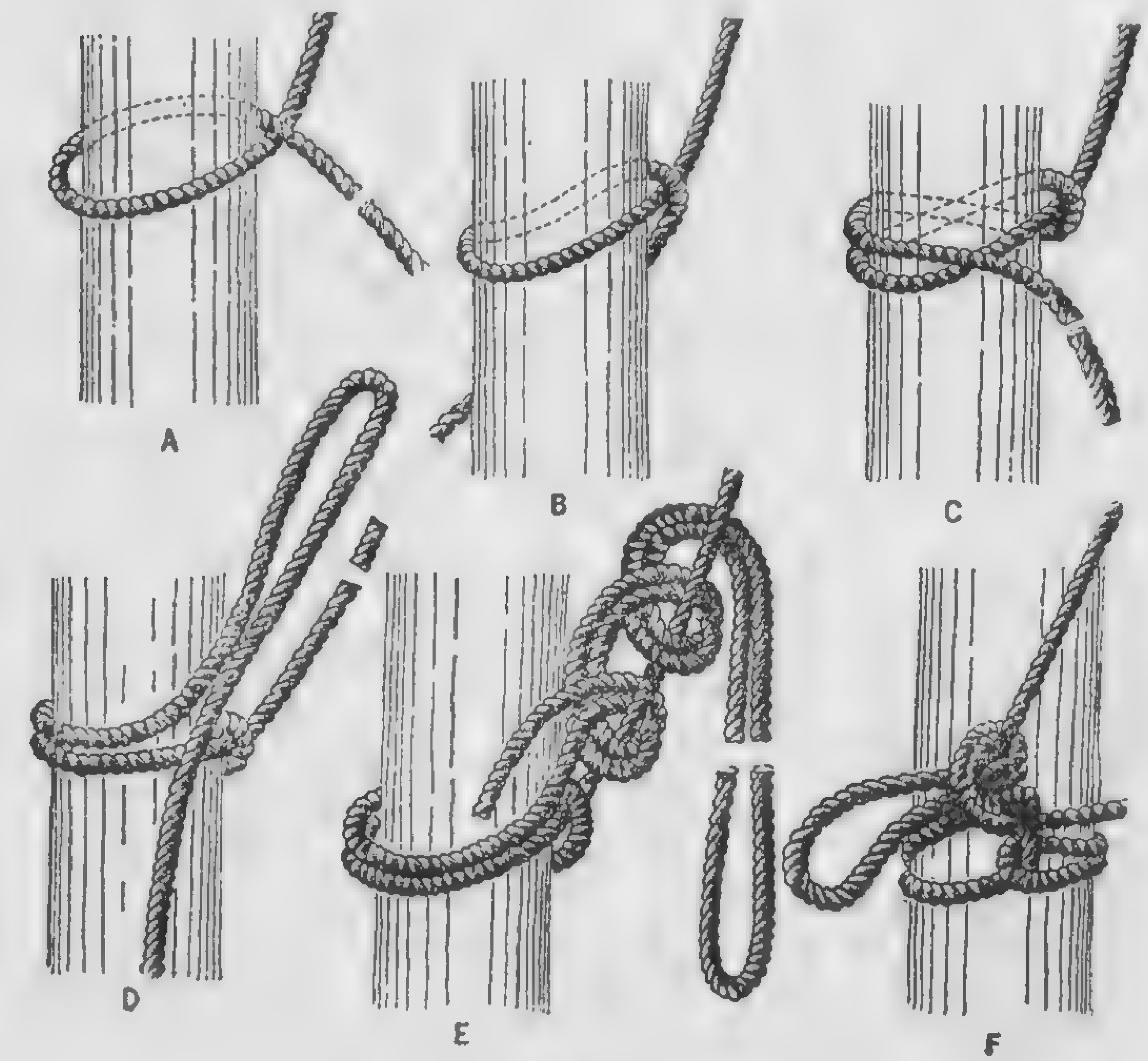



Fig. 18

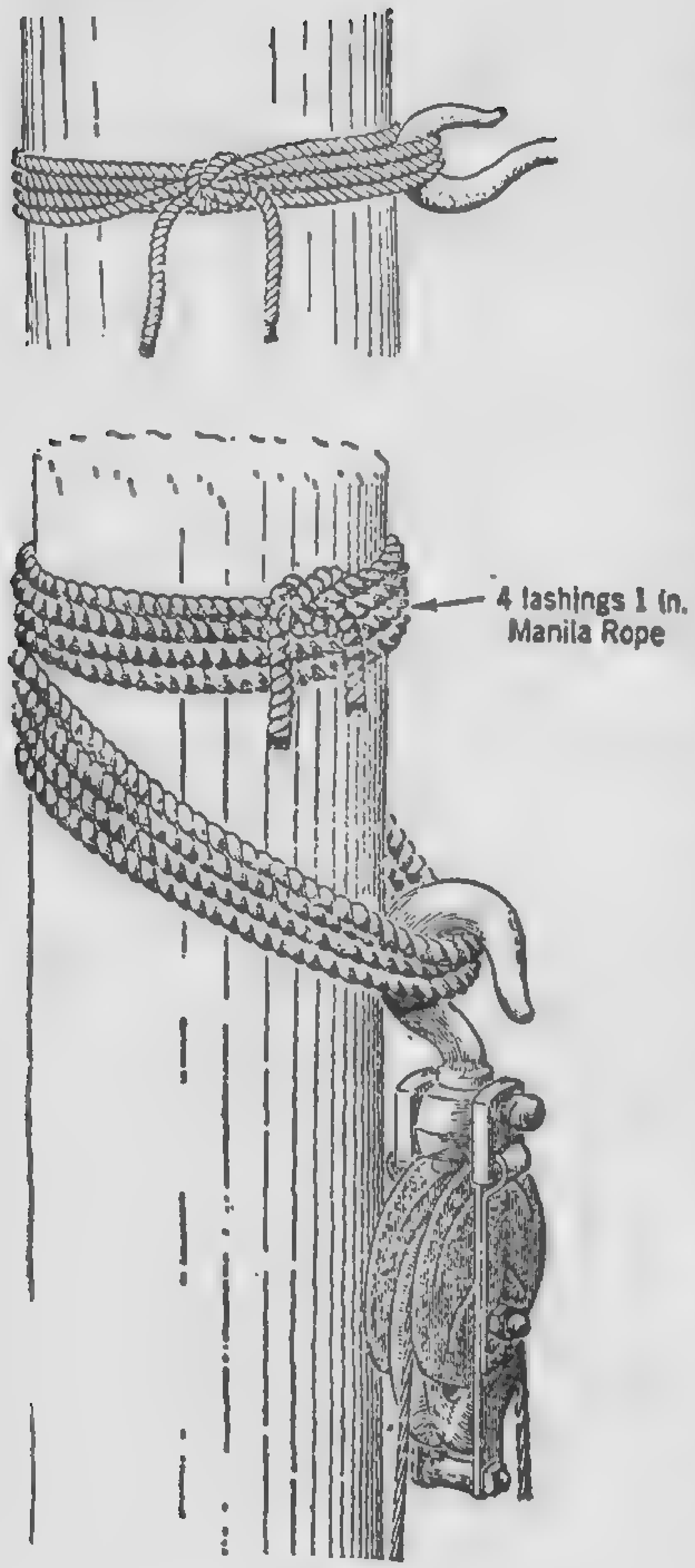


Fig. 19

leading from the splicers platform to the pole, ladders, and other supports. See Fig. 18.

1. Select the side of the platform from which the splicer is to work. Grasp loose end of guy rope from opposite side of the platform and pass it around the pole, about 3′ from the ground, and pull tight. Keep the guy rope clear of steps and avoid blocking the climbing space.

2. Take a turn over and around the standing part of the rope with the loose end, and pull to the desired tension.

3. Pass the rope around the pole so that it crosses the first turn. Hold the free end of the rope in this position to snub pull on the platform. Pull to the desired tension.

4. If the free end is too long to handle, double the rope as shown in 18-*D*.

5. Secure with two half-hitches on the standing rope. The completed knot is shown in 18-*F*.

6. The other guy rope shall be secured on the same side of the pole, near the turns of the first guy rope. Since this guy leads from the opposite direction, it must necessarily be snubbed in the opposite direction.

**Lashing.** Lashings are used when a temporary attachment is desired. The ease of attaching and detaching and the safety factor will determine the type of lashings that will be used in various conditions. Lashings to be used where the pull is perpendicular to the axis of the pole and where the pull is parallel to the axis of the pole are shown in Fig. 19.





**TABLE 2**

**Required Number of Turns Through Hooks of Blocks**

| Size of Block | Sizes of Rope Lashings | | | |
|---|---|---|---|---|
| | 3/8″ | 1/2″ | 5/8″ or 3/4″ | 1″ |
| 3-inch, 1 sheave..... | 2 | .. | .. | .. |
| 3-inch, 2 sheave..... | 3 | 2 | .. | .. |
| 3-inch, 3 sheave..... | 4 | 3 | .. | .. |
| 4-inch, 3 sheave..... | .. | 4 | 3 | .. |
| 6-inch, 3 sheave..... | .. | .. | 4 | 3 |
| 8-inch, 3 sheave..... | .. | .. | .. | 4 |
| 6-inch, Snatch ...... | .. | .. | 4 | 3 |
| 8-inch, Snatch ...... | .. | .. | .. | 4 |

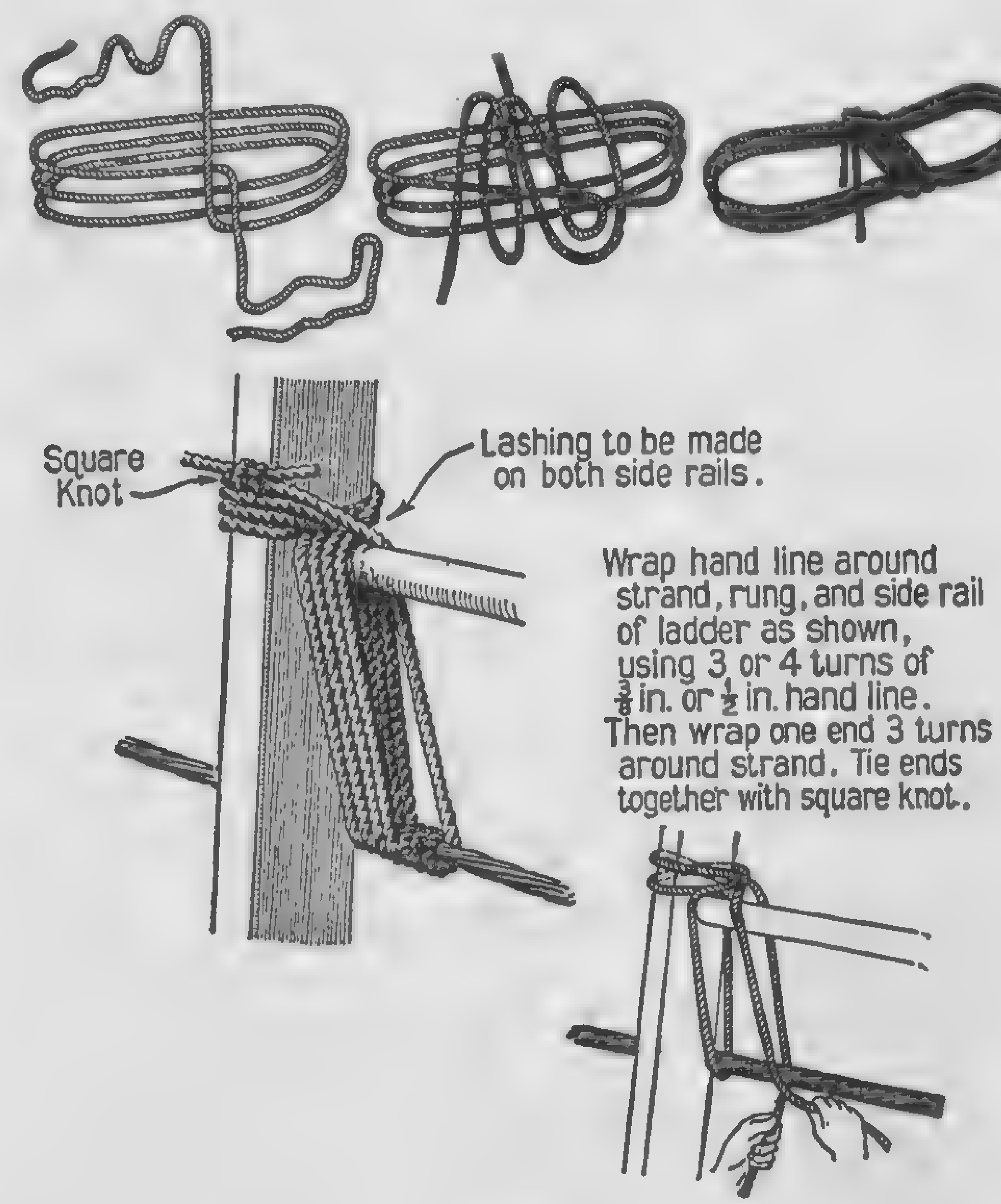


Fig. 20

The rope used for lashing should be of the size shown in Table 2, and in good condition. Rope which has been discarded as unsafe for pulling line or for use in blocks should not be used for lashings. When lashing a block to a pole, the number of turns around the pole shall be the same as the number of turns through the hook.

Fig. 20 shows the type of lashing to be used when lashing two poles together. Fig. 20 also shows the lashing used in securing a ladder to a messenger. A ladder should not be moved after it has been lashed to the messenger.





PART 7

# Blocks and Tackle

**General.** The parts of a block are the shell, sheave, hook, becket, becket bolt, bushing, cotter pin, center strap, outside strap, and roller bushing. See (a) of Fig. 1.

The terms commonly used in reference to blocks are as follows:

*Tackle.* An assembly of ropes and blocks. The rope is commonly called the fall

*Running Block.* The block attached to the object to be moved

*Standing Block.* The block attached to the fixed support

*Overhaul Blocks.* To separate or spread blocks in a tackle

*Run in Block.* To bring blocks closer together

*Chock-a-Block.* Blocks of a tackle in contact

*Standing End.* End of a rope fixed to the block

*Running End or Fall Line.* The free end of the rope in tackle

*Return.* The rope between two blocks

*Reeving of Blocks.* To pass rope over the sheaves of blocks to obtain mechanical advantage

For an explanation of mathematical principles involved, see section on Physics.

**Standard Blocks.** Standard blocks are furnished in the sizes shown in Table 1, and are equipped with the open type hook unless ordered with shackle. Table 1 shows the standard sizes and types of blocks, together with their working strength and the size of rope to be used. The size of blocks is determined by the length of their shell and the number of sheaves.

The hooks of the standard and snatch blocks have been designed so that they start to open at approximately 70% of the

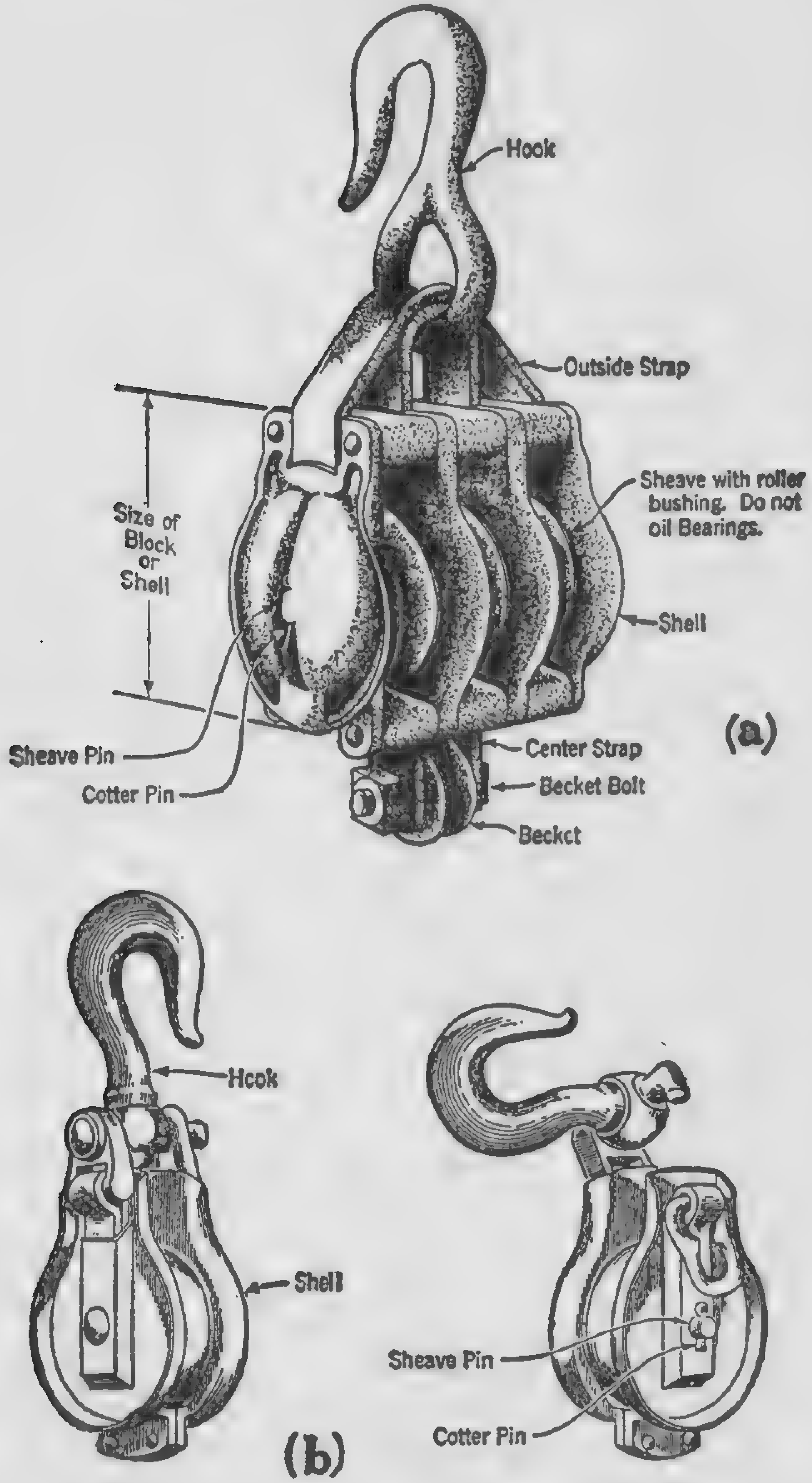



Fig. 1

maximum load they will carry, thus acting as a visible safety link to warn against overstressing, before complete failure of the block. To obtain the maximum strength, the load should be applied at





**TABLE 1**

| Size of Blocks (Inches) | Number of Sheaves | Working Strength of Hooks (Lbs.)* | Size** of Rope | Suggested Length (Ft.) | Maximum Load That May Be Applied to New Small Rope | Maximum Load That May Be Applied to New Large Rope |
|---|---|---|---|---|---|---|
| 3 | 1 | 2100 | ⅜ or ½ | 50 | 400 | 700 |
| 3 | 2 | 2300 | ⅜ or ½ | 75 | 400 | 600 |
| 3 | 3 | 3900 | ⅜ or ½ | 100 | 400 | 650 |
| 4 | 3 | 4600 | ½ or ⅝ | 150 | 700 | 800 |
| 6 | 3 | 8600 | ¾ | 200 | 1400 | ... |
| 8 | 3 | 12000 | 1 | 275 | 2300 | ... |

* Maximum load permitted on hooks.
** The smaller size rope shall be used, in general, where the weather conditions are humid.

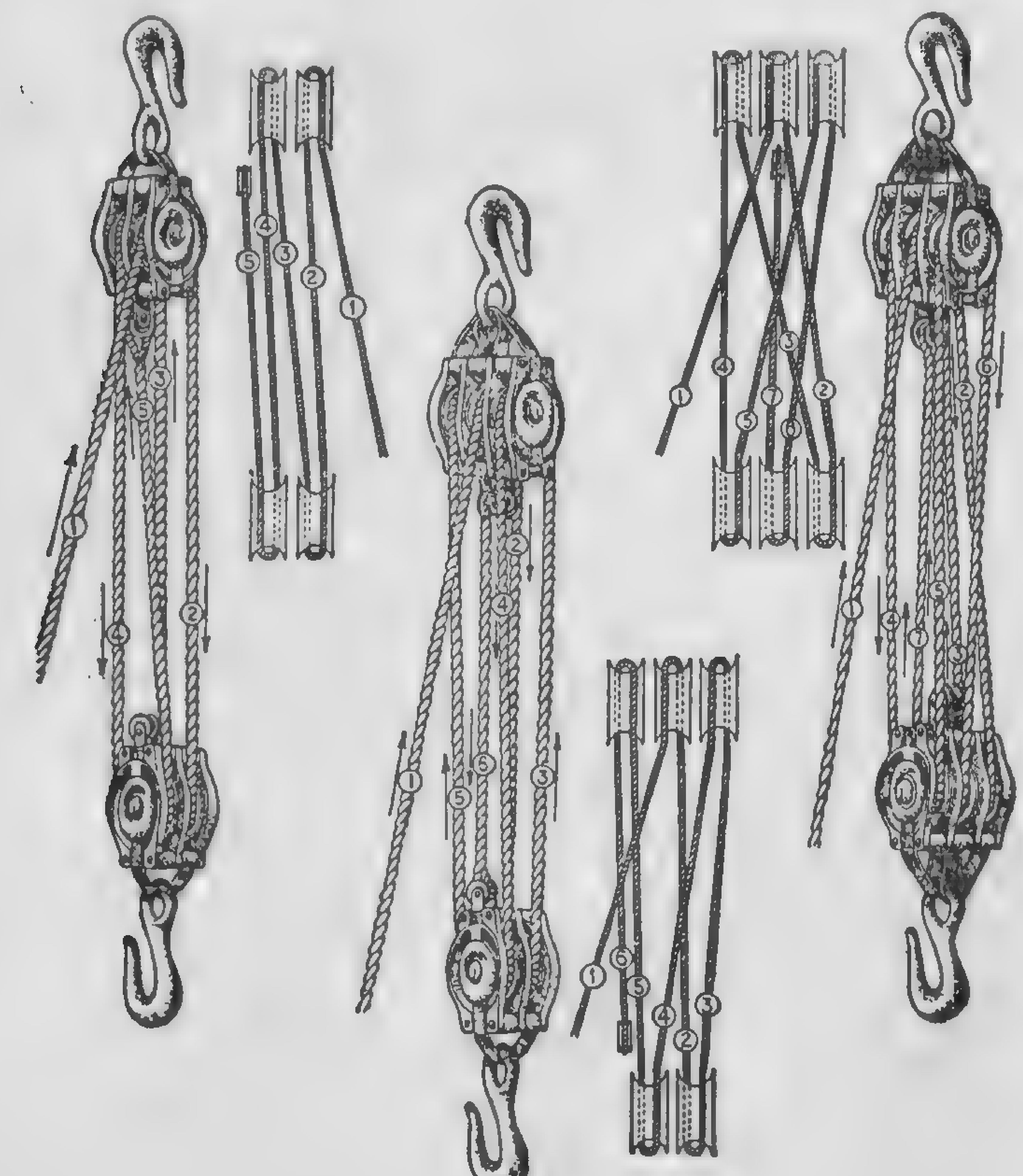


Fig. 2

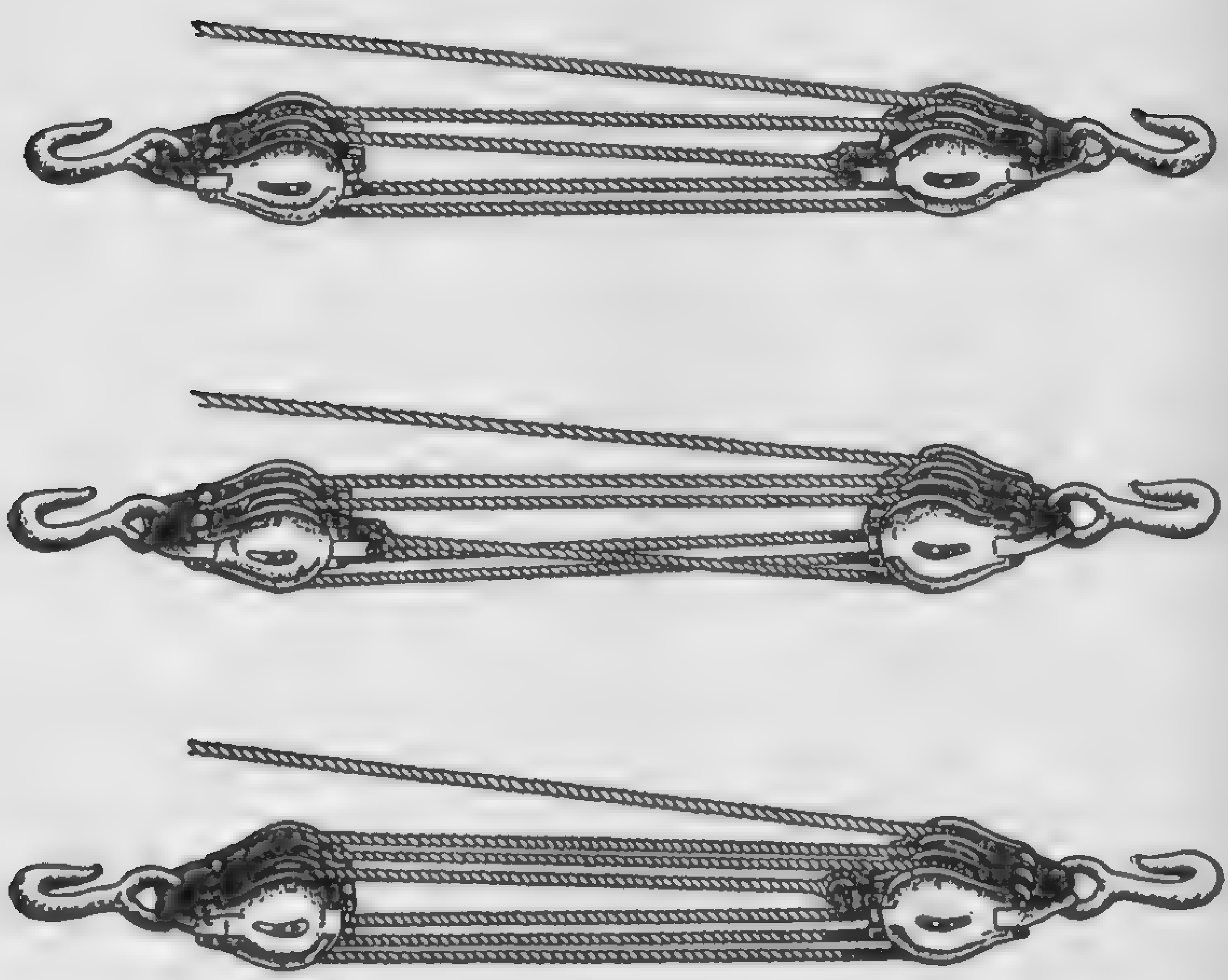


Fig. 3

the lowest point of curvature of the hook. The maximum working strength of the hooks, as given in Table 1, is based on the load being applied at the lowest point of curvature of the hook. It is impracticable to give the strengths of the hooks for all conditions, as the load may not always be applied in the same manner. When blocks are in use, the hook should be under observation at all times, to determine if the hook has the required strength to withstand the applied load.

**Manila Rope Snatch Blocks.** Snatch blocks are furnished in two sizes: 6″ or 8″. The hooks have a working strength of 11,000 pounds and 17,000 pounds respectively. This working strength is approximately 70% of the maximum load they will carry. The 6″ block is intended for use with 5/8″ or 3/4″ manila rope and the 8″ block is intended for use with 1″ or 1 1/4″ manila rope. Snatch blocks are illustrated at (b) in Fig. 1.

**Reeving of Blocks.** It is important that blocks be reeved properly to have them operate to the best advantage and avoid jamming, which would lose time and possibly cause an accident. The 2- or 3-sheave blocks shall be reeved in either of the ways as shown in Figs. 2 and 3.





When reeving with new rope, place the rope under slight tension. The fall line should emerge from the center sheave of a 3-sheave block. This causes the hoisting strain to come on the center of the block, preventing it from turning and cutting the rope on the block shell. When reeving by this method, Fig. 2, the sheaves of the two blocks should be placed at right angles to each other.

Where there is a possibility of the rope being tangled, when reeving by the method shown in Fig. 2, the blocks may be reeved left over right, as shown in Fig. 3.

**Rigging.** The type of rigging used will depend upon the weight to be handled and the available motive power. The simplest rigging that will adequately perform the work should be selected. Luffing tackle is a commonly used type of rigging. A simple definition of luffing tackle is: additional tackle (blocks and necessary rope) attached to the fall line of the main tackle (tackle attached to the load). Fig. 4 shows luffing tackle used two different ways, lifting a load and hauling a load.

When the load to be handled is greater than can be handled safely by the workmen, then block and tackle shall be used to gain a mechanical advantage. For practical purposes, the weight capable of being lifted is equal to the applied force times the number of ropes leaving the movable block. For example, if a man can exert a force of 130 pounds on the fall line of a three-sheave tackle, he will be able to lift 6 times 130 or 780 pounds. This assumes the fall line leaves the fixed block as in *lifting* a load, Fig. 4. If the fall line leaves the movable block as in *hauling* a load, Fig. 4, the same man can lift 7 times 130 or 910 pounds.

**Selecting Proper Size Blocks for Work to Be Performed.** To do this, it is necessary to know the approximate weight to be handled, the motive or lifting power available, and the strength of the hooks of the standard blocks. Knowing the load and the available power, calculate the number of sheaves required by dividing the load by two times the power. If this result is three or less, select one of the standard blocks with the number of sheaves as calculated and a hook strong enough to withstand the load. If this result is over three, it will be necessary to select a system of rigging from the standard blocks available. This rigging will

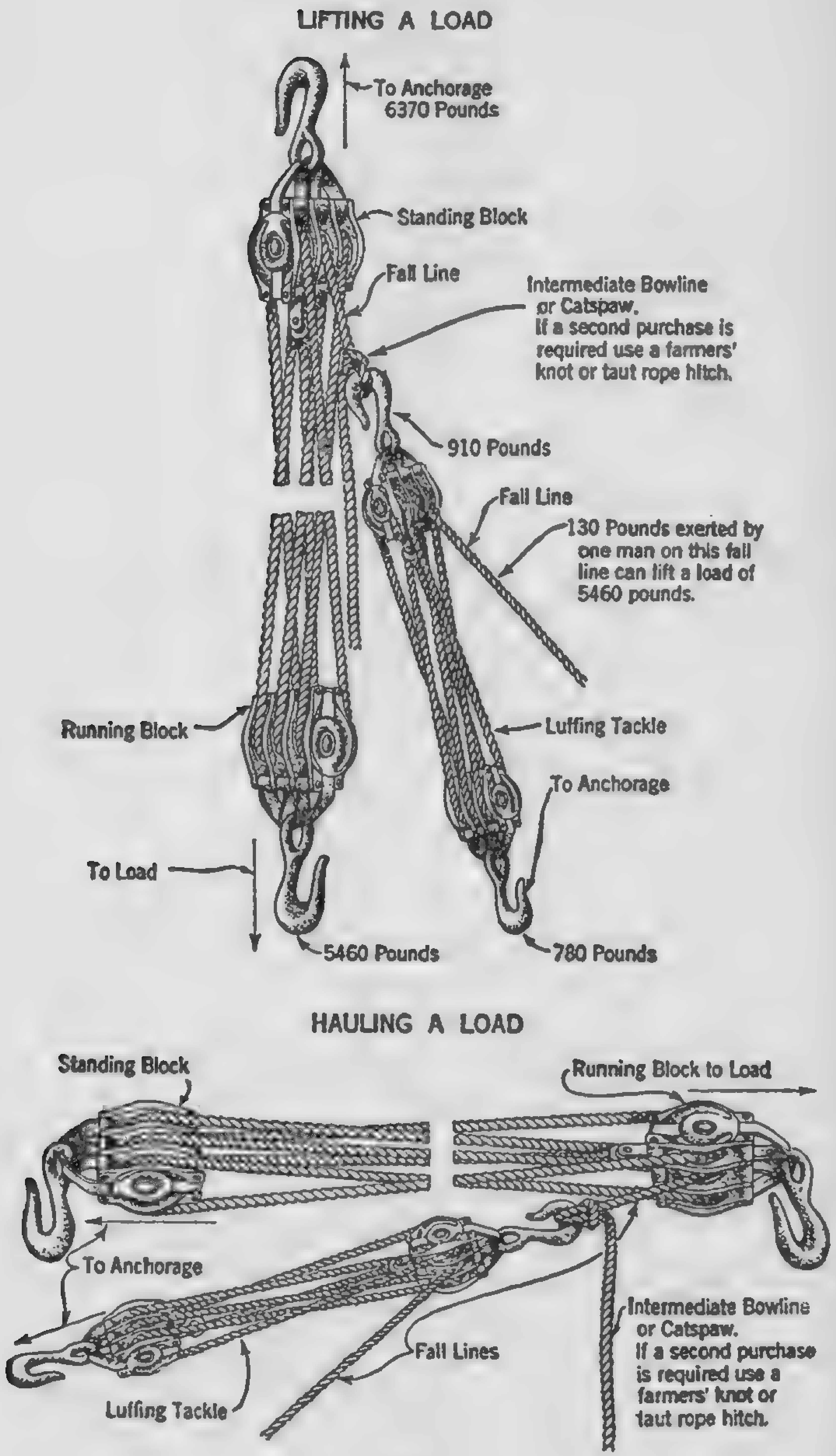



Fig. 4





require luffing tackle, which in general is a 3-sheave arrangement. See Fig. 4. When using luffing tackle, remember that for practicable purposes, the stress in the fall line of the tackle attached to the load is equal to the force applied to the fall line of the luffing tackle, times the number of ropes leaving the movable block of the luffing tackle, which will be six or seven.

Refer to section on Physics for explanation of mathematical principles.

To determine the number of sheaves required in the tackle attached to the load, divide the load to be lifted by twice the applied power. Select a block with a hook capable of withstanding the load. Be sure that the load applied to the fall line of the tackle attached to the load is not too great for the size of the rope.

*Example:* Refer to Fig. 4, (Lifting a Load). 5460 pounds to be lifted by one man who can exert a force of 130 pounds.

To find the number of sheaves required $5460 \div (2 \times 130)$ or $5460 \div 260$ equals 20 (approximate).

The number of sheaves required is greater than three, therefore luffing tackle is required. Three-sheave blocks will be used in the tackle attached to the load, with the fall line leaving the fixed block, which makes the man capable of lifting 6 times 130 or 780 pounds.

Number of sheaves required in luffing tackle equals $5460 \div (2 \times 780)$. (Use 3.)

Using 3-sheave blocks in the luffing tackle, the fall line leaving the moving block, the man can lift 7 times 130 or 910 pounds.

With a 910-pound pull exerted on the fall line of the main tackle (by use of the luffing tackle), the man will be able to lift 6 times 910 or 5460 pounds.

When the approximate weight and motive power are known, the proper size blocks can be selected from Table 1, in most cases.

## SAFETY PRECAUTIONS

Safety to life and property requires that rope and blocks be well cared for. A few precautions in addition to those previously listed in the text are:

1. A hook that has begun to straighten shall be discarded immediately.

2. Do not use blocks with sheave holes too small to give clearance, between the sheaves and the sides and top of the shell.

3. When moving from one location to another, do not drag rope on the ground.

4. Do not stand unnecessarily close to, and never straddle, rope under tension.

5. Do not stand in the inside angle, or in the path of rope being paid out or under tension.

6. Do not use frozen rope.

7. The hand line shall not be attached to the belt, when working on poles. Make it fast to the crossarm or to the pole.

8. Hand line or other rope secured aloft, when not in use, shall be secured at a point near the ground to prevent it from being blown about.

9. Rope shall be placed as to create no obstruction on highways or thoroughfares, unless unavoidable; in that case, place a man to warn traffic.

10. Gloves should be worn when handling new rope to avoid the possibility of injury from fiber slivers.





PART 8

# Woodsmanship

Following is a descriptive list and instructions for the use and care of some of the essential tools used in tree felling, together with instructions in their use.

## USE AND CARE OF TOOLS

Safe and skillful use and care of tools used in felling trees can be acquired by men with little or no prior experience in such work through observing certain precautions and following the simple rules explained herein.

**Axes.** Both single and double-bitted axes, as shown in Fig. 1, are extensively used in felling trees. However, double-bitted axes are usually preferred, since one blade can be used for materials that quickly dull the edge, such as knots, and the other blade can be saved for normal chopping. For trees less than 1½ feet in diameter a 3-pound ax serves the purpose, but for larger timber a 3½-to 4-pound ax is best, because it helps the worker to obtain deeper bites and therefore more efficient chopping.

Most chopping accidents are due to carelessness. Before starting to swing an ax, look around; clear away overhanging limbs and all undergrowth or small trees that may interfere. If an ax strikes such interference, it is apt to glance and swing wild. Be sure that no other workmen are within range of the ax swing. Once sure of safe swinging space, the chopper's eye should be kept on the spot being chopped. In chopping, always keep a solid grip with the hand uppermost on the handle. See Fig. 2. Be sure to swing the ax away from the legs and body so that, if the ax misses the work or glances, it will not cause an injury. Try always to keep one edge of the

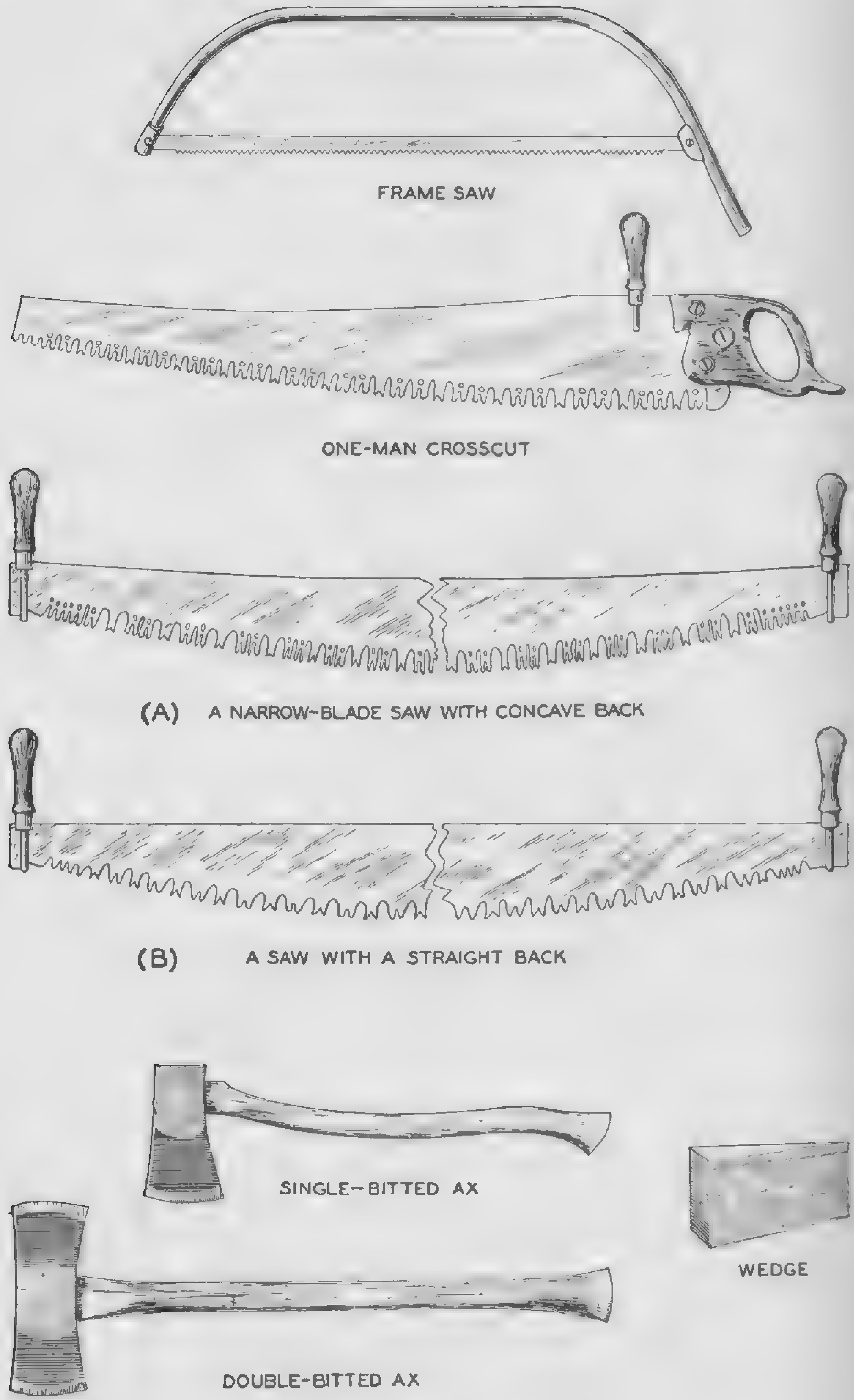



Fig. 1. Tools Used in Felling Trees





double-bitted ax sharp, using the duller edge in all chopping where there is any chance of striking knots, the ground, or rocks.

Never throw an ax, and never leave one lying on the ground. When not in use axes should be enclosed in guards or the blade should be firmly driven into a log or stump. Never use a single-bitted ax in place of a sledge hammer, since this results in spreading the "eye" and thus ruining the ax.

Fig. 2. How to Hold an Ax

When going through forest, brush, and rough country, the best way to carry an ax, whether single- or double-bitted, is to carry it in the hand, grasping the handle close to the ax head, with the bit at right angles to the ground. See Fig. 3. Double-bitted axes, especially, should never be carried on the shoulder in rough country.

For ax sharpening in the woods, a flat file can be used to remove nicks and a whetstone for conditioning the cutting edge.

**Saws.** There are three kinds of saws most frequently used in felling trees and cutting the logs to required lengths. They are

called Two-man Crosscut, Frame, and One-man Crosscut saws. See Fig. 1.

Two-man crosscut saws are of two varieties as shown at *A* and *B* in Fig. 1. The saw at *A* has a narrow blade and a concave back. This saw is used for small timber and its concave back facilitates wedging. The saw at *B* has a straight back and is generally used for large timber. Crosscut saws 5½ or 6 feet long are advisable for the ordinary run of timber, but for large trees a saw 2 or 3 feet longer than the stump diameter should be used. For soft woods a

Fig. 3. How to Carry an Ax

Fig. 4. How to Carry a Crosscut Saw

cutting edge, as shown at *A*, in Fig. 1, is recommended. For hard woods a cutting edge, as shown at *B*, in Fig 1, is recommended. The hardwood edge is also used for mixed hardwoods and softwoods.

A pop bottle stoppered with straw, long grass, sedge, or pine needles makes a sprinkler for oiling crosscut saws. The stopper material is crowded into the neck tight enough to stay in place, yet loose enough to permit the oil to spray out when the bottle is turned over and given a light, jerky, stroke.

The frame, sometimes called a bow saw, can be used efficiently for felling trees 10 inches or less in diameter. Besides felling small





trees, this saw can be used by one man in sawing such timber into required lengths.

The one-man crosscut saw can be used in felling small trees, but it is especially usable in cutting moderate-sized timber to length.

When not in actual use, saws should have their cutting edges protected by some sort of a guard. This precaution will prevent injury or dulling of the teeth.

Never carry a crosscut saw under the arm, but always carry it balanced on the shoulder, with the teeth pointing out, as shown in Fig. 4.

Sharpening of crosscut saws (filing) should always be done by some one skilled in that procedure. Never attempt to file a saw in the woods.

In using a two-man crosscut saw, one point should be kept in mind always—do not try to push the saw. After one man has pulled the saw toward him the other man, without help, should pull the saw toward him.

**Wedges.** Good and serviceable wedges, Fig. 1, can be made from steel or from any tough, shock-resisting wood, such as dogwood, persimmon, gum, hickory, ash, beech, birch, maple, or oak. When making steel wedges, malleable steel or iron should be used.

An ordinary wedge is about 4 inches wide by 7 inches long and it should have approximately an ax blade taper.

## FELLING TREES

The usual procedure in felling trees is to select the direction for felling, make the undercut, and saw off the bole. With a three-man crew, one man usually brushes out a clear space sufficient to swing an ax or pull the saw; he also makes the undercut, marks off the log lengths, and lops off limbs. Felling straight trees with well-balanced crowns is relatively safe and simple. Such trees can be dropped in any direction. As a general note of caution, however, any felling is hazardous on windy days. Make stumps as

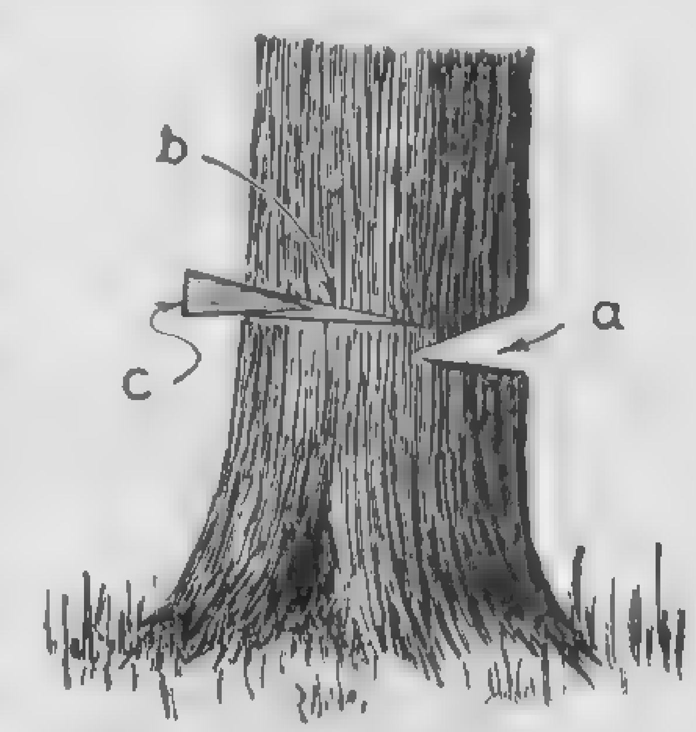



Fig. 5. Common Method of Felling a Straight Tree: (a) Undercut; (b) Saw Cut; (c) Wedge in Saw Cut.

low as possible, both to gain extra material and to avoid unnecessary obstructions when logs are hauled out. The statement is sometimes made that stump heights should average the diameter of the tree; but for sound timber this is too high. Stumps 6 to 8 inches high for trees up to 20 inches in diameter are about right.

Start the undercut with the saw on the side facing the direction of the fall, and on a straight tree carry it about one-third the diameter toward the heart, as shown in Fig. 5, at point *a*. The scarp is

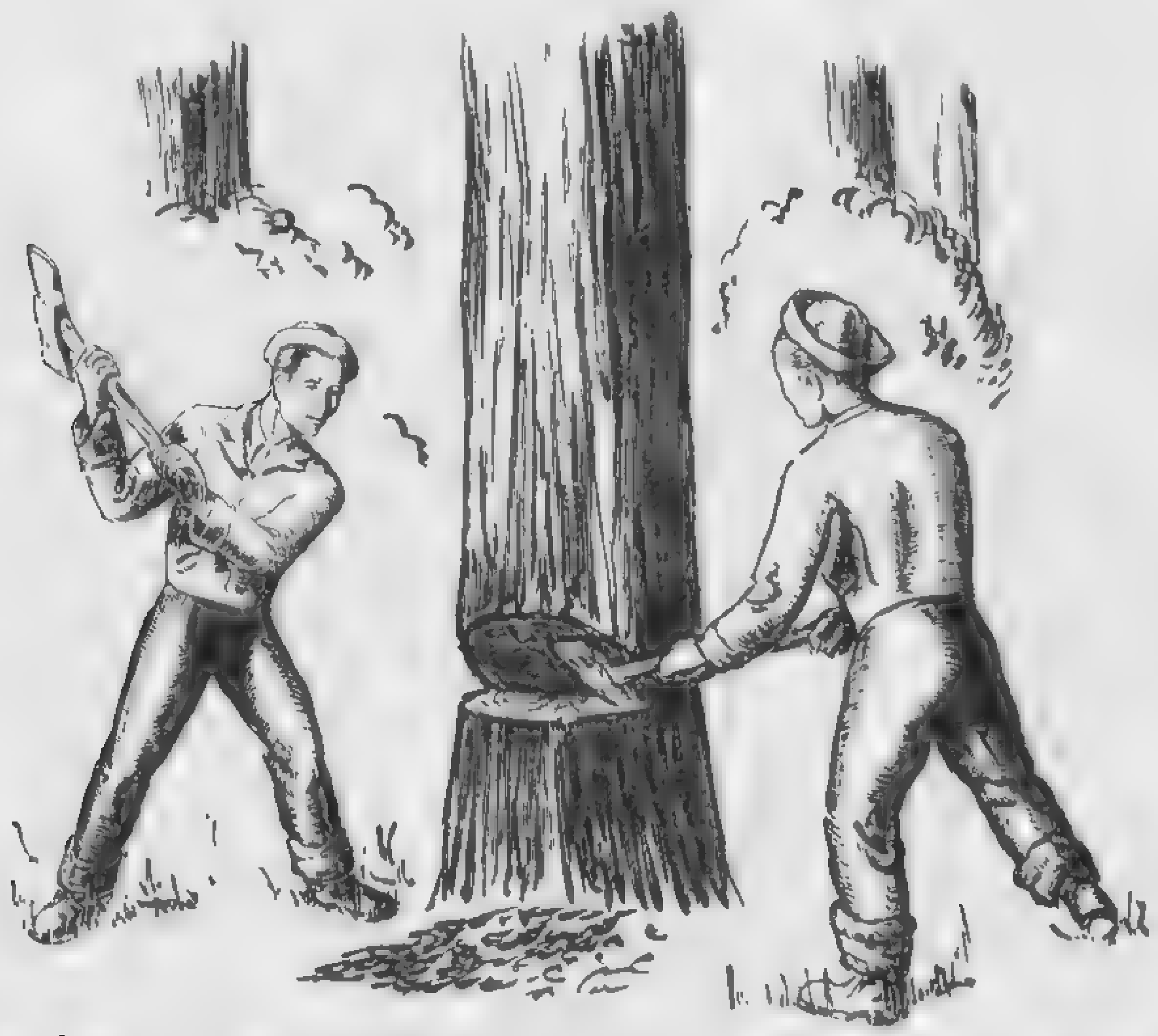


Fig. 6. How Axes Are Used to Chop Out the Scarf After the Undercut Has Been Made

then chopped out with the ax for the entire width and depth of the saw cut, as shown in Fig. 6.

The main saw cut is started on the opposite side of the tree slightly above the level of the base of the undercut, as shown at *b* in Fig. 5 and in Fig. 7. A good practice with trees having a flinty bark, like the black oaks and the hickories, is to clip off the bark where the saw cut is to be made. Sawing is continued until the saw binds and a wedge must be driven into the cut to release it, as shown in Fig. 5, at *c*. Toward the termination of the cut the sawing speed is increased to sever as many fibers as possible for a clean cut.





As the tree starts to fall, the saw is withdrawn, and the fallers move away from the stump so as not to get caught if the tree kicks back or bounces aside. All fallers should copy experienced woodsmen in their alertness to the great hazard of falling limbs (often termed "widow makers"), which may be torn off as the tree drops.

In determining the direction a tree should be felled, consider best how to avoid damage to neighboring trees and to the tree itself, and how to make it easy to get out the logs. See Fig. 7. It is dangerous to fell a tree directly uphill on steep slopes because it may

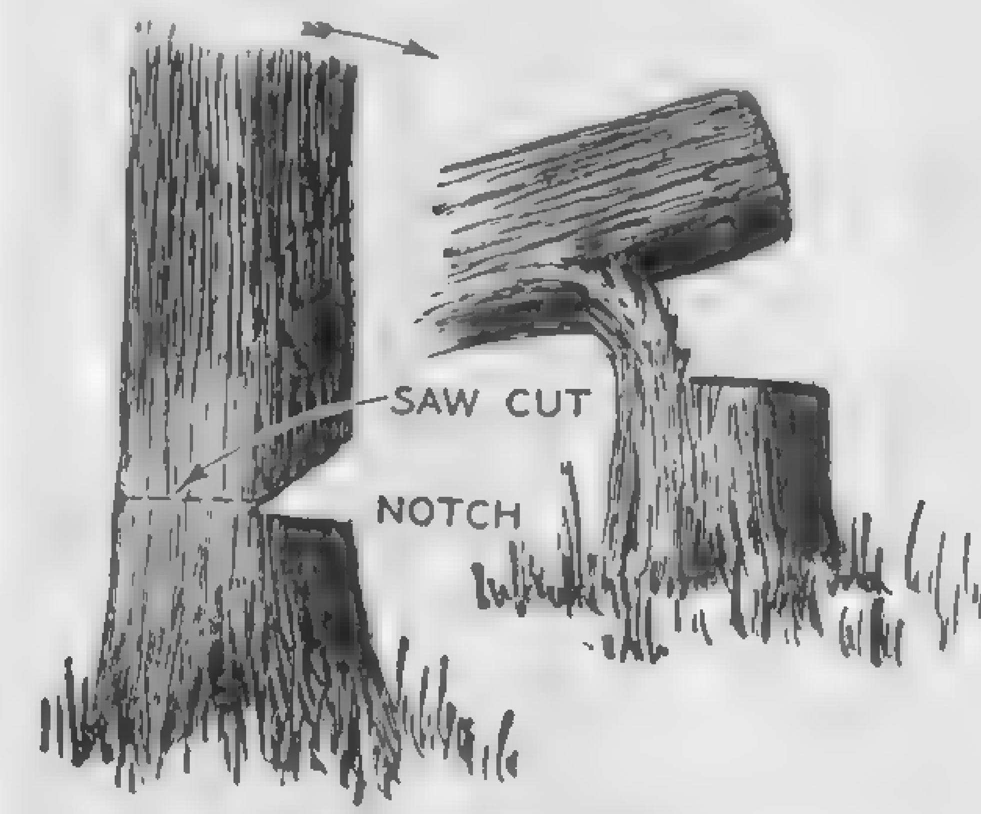



Fig. 7. Proper Felling

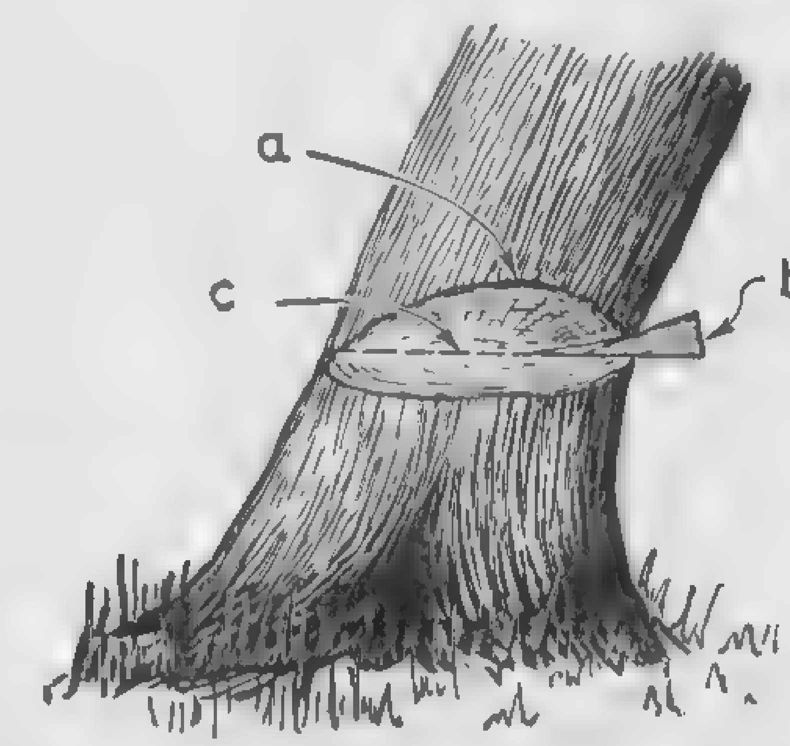



Fig. 8. Three Steps in Felling an Unbalanced Tree in a Direction Other Than That of the Natural Fall: (a) Undercut Halfway Through on Side of Desired Fall; (b) Saw Cut on Side of Lean, as Nearly Halfway Through as Practicable, Strongly Wedged; (c) Final Saw Cut on Side Away From Desired Fall, in Which Wedge Is Driven to Force Fall to Opposite Side.

suddenly start sliding downhill. If a tree is felled so that it is supported only at the ends, it will be hard to saw up.

If a falling tree gets caught in neighboring trees, it can sometimes be brought down by felling another tree across it as near the supporting tree as possible. It is also sometimes possible to pry the grounded end or pull on it with power until the end suspended in the tree is clear. A final but dangerous practice consists in felling the supporting tree with an ax in accordance with instructions for trees with excessive lean.

In order to minimize work in getting out logs which might be buried beneath the limbs, branches, and foliage of other felled trees, a good practice is to fell in groups toward a common center. A variation used in clear cutting is to fell the trees in strips so

that the crowns are in the same direction and form a continuous windrow.

Trees with a large amount of lean, crook, or unbalanced crown should, as a matter of safety, be felled with an ax and in the direction in which the tree leans or is weighted. The undercut should be carried past the heart to where the tree is so weakened that a few cuts on the opposite side will bring it down. Such trees are likely to split and kick back. but a deep undercut somewhat corrects this.

If it is necessary to fell a leaning, crooked, or unbalanced tree in some other direction than the natural fall, the undercut should be made on the side toward which the tree is to be felled and carried to the center, as shown in Fig. 8, at point *a*. The saw should then be started on the side of the natural fall and the saw cut continued, if possible, to the center. When the saw is removed, a wedge should be driven into the cut, as shown in Fig. 8, at *b*. Next, a saw cut should be started opposite the undercut and continued until the tree shows signs of weakening, when the saw is removed. Wedges should then be used to force the tree in the direction desired, as shown in Fig. 8, at *c*.

In cases where splits resulting from an unbalanced or unsupported condition are likely to develop as the saw works through, a good practice is to support the sagging portion with an upright from bole to ground.





PART 9

# Glossary of Shop Terms

## A

**abrading tools:** Small hand tools that cut by friction, as an oil stone or file.

**abrasive:** A substance used for abrading as in grinding, polishing, etc.

**adjustment:** The controlled movement or setting of the parts of a machine, tool or device.

**ailerons:** Flaps at or near each wing tip (of an airplane) under the control of the pilot, and manipulated by him so as to give a rolling motion to the aircraft on its fore and aft axis.

**align:** To bring into line; to true up.

**alternate:** Every other one in series as in saw filing.

**angle:** The figure formed by two lines which meet in a point; the space bounded on two sides by such lines.

**anneal:** To soften a piece of steel or other hardened material by heating and allowing the object to cool at a very slow rate, usually with the furnace or by burying it in lime.

**anvil:** A metal block as used in a saw set to shape the tooth.

**approximate:** Close to, somewhere near.

**apron:** That part of a machine which is in front of and serves as a cover for other parts.

**arbor:** A shaft to which a power-driven saw blade or cutter is fastened.

**arc:** A part of a circle.

**arc weld:** To unite metallic parts by means of an electric arc.

**assembly:** 1. State of being assembled. An assembly drawing is one showing various mechanical parts in correct positions. 2. A complete mechanism.

**awl:** 1. A marking tool used as a knife blade or pencil (scratch awl). 2. A small pointed tool for making holes which are to receive nails or screws.

**axis:** The center line through an object, usually lengthwise.

## B

**babbitt:** A metal made up of tin, antimony and copper, sometimes lead is used—a bearing metal.

**back gear:** The gears on a machine that are used to obtain power or reduce speed.

**ball peen:** A type of machinist's hammer having a peen that is shaped like a ball.

**bar:** A piece of steel used to obtain mechanical advantage such as pinch-bar, crow-bar, etc.

**bastard:** Not standard—a bolt having an uncommon size or thread—a grade of file between smooth and coarse—no reflection on parentage.

**becket:** An opening or eye to which the stationary end of a rope is tied.

**beechwood:** A hard wood, very dense fibre much used in carpentry hand tools.

**bellied:** Bulging outward.

**bench trimmer:** Hand-operated machine for cutting small wood mouldings.

**benzine:** A liquid solvent used as a cleaning agency by painters.

**bevel:** Slanting edge or surface as pertaining to the bevel of a saw-tooth—woodwork.
**bevel square:** A carpenter's small square with an adjustable blade.
**bight:** One or more loops of a rope, used as temporary holding power.
**bit:** 1. A boring tool which fits into the socket of a brace, by which it is rotated. 2. The cutting iron of a plane. 3. The copper head of a soldering iron. 4. The blade of a hatchet, an ax, or like tool.
**blade:** The larger part or section of the steel square.
**block and tackle:** A pulley and rope arrangement to increase the lifting power applied.
**blow:** Forceful contact between two moving bodies as a hammer blow—forcing air through molten steel as in the Bessemer process.
**boiled oil:** Linseed oil treated by refining to hasten its drying qualities.
**bole:** 1. A round body; akin to a ball. 2. An unglazed opening in the wall of a building, for admitting light and air. 3. A recess or cupboard in a wall.
**bolt cutter:** A tool designed to cut small diameter bolts, rivets, etc., having long handles and short cutting jaws—a machine designed and used exclusively for threading bolts or rods.
**bore:** To machine a hole by means of a boring tool held in a lathe or boring machine.
**boring bar:** The supporting shaft that holds the tool in position while boring.
**boss:** A surface which projects above another surface, as on a casting.
**bowline:** A knot that holds well and is easy to untie, much used.
**brads:** Small round head nails, in various diameters, for fastening mouldings.
**braze:** To solder with hard solder or with brass.
**breaking strength:** The extreme stress or strength of a rope or cable in pounds.
**bridge:** A device, usually wood, used to cross a large hole so that the hole center may be located.
**brittle:** Easily broken.
**broach:** To finish a hole or a surface with a tool having a series of cutting teeth on its outside diameter, the tool being pushed or pulled in operation.
**bronzing:** To decorate a surface with bronzing materials such as pale gold bronze.
**buff:** To polish with a revolving disk made of layers of cloth charged with an abrasive.
**burnish:** To polish to a brilliant finish by using a burnishing tool and pressure.
**burr:** A rough projection on a machined or cast surface. Not to be used as a holding device.
**bushing:** A metallic lining for a hole, as in the hub of a wheel.

## C

**calcimine:** A decorating material made from whiting, glue, color and water.
**caliper:** An adjustable gage used to obtain size or locate a dimension.
**cam:** Rotating or sliding piece or projection, as on a wheel, to impart peculiar movement or to receive it—a lever action attachment to control the movement of a plane blade.
**camber:** A slight arch or rise in the middle.
**camouflage:** To make an object less visible or noticeable.
**cap iron:** The metal cap that holds the plane iron in position.
**carbon:** The main hardening agent in tool steel—the element having more different forms than all other elements combined. A diamond is pure carbon in crystalline form.
**carborundum:** A manufactured material used for grinding and polishing.
**carburize:** To impregnate with carbon. For example, steel is put into boxes or pots with charcoal or other carburizing agents and heated to the critical temperature (approx. 1650° F.). Carbon generated by the agent is picked up by the steel; length of time at high temperature governs the amount of carbon pickup.
**case-harden:** To harden steel in such a way that a hard outer layer or case is formed, leaving the core tough.
**casein:** A milk powder used in the making of glue.





**cast:** An object that has been formed by pouring molten metal into a mold and allowed to cool is said to be "cast."
**cemented:** Fastened together by some substance that resists separation.
**chalking:** Disintegration of a painted surface by powdering.
**chamfer:** The flat surface formed by cutting off a sharp corner, usually 45°.
**chase:** To form screw-threads in a lathe by means of thread-cutting tools. Distinguish from thread cutting done with dies.
**chattering:** Vibration between the work and tool resulting in uniform roughness of the machined surface.
**checkered:** Uniform markings usually at right angles to each other.
**cheek:** That part of a hammer side opposite the eye.
**chill:** To surface-harden. Sudden cooling of a metal or a mold.
**chip:** Pieces of metal removed from an object by the cutting process.
**chipping:** Cutting away pieces of metal by the use of a hammer and chisel.
**chisel:** A cutting tool operated by hand, having the cutting edge shaped to obtain the desired groove.
**classification:** The grouping under which various machines, tools and materials are most easily identified.
**clearance:** The space left by the removal of material below the cutting edge of a tool, to permit the tool to cut instead of rub.
**cold metal work:** Forming an object by bending or distorting without heating.
**cold rolled:** Cold forming to size and shape by means of pressure between two or more cylindrical surfaces.
**composition:** The result of combining two or more elements. Babbitt is a composition.
**compound:** Where two or more materials are put together and form a totally different material. (Babbitt is different from any of its elements.)
**concave:** Hollow and rounded, as the interior of a sphere or circle; incurved.
**concentric:** Where two or more objects have a common center.
**constant:** That part of a formula that does not change. 3.1416 is the "constant" in the formula, diameter x 3.1416 = circumference.
**construct:** To put two or more objects together to make another object—to lay out by definite dimension.
**convex:** Curving outward.
**coolant:** A general term applied to any mixture of liquids used to reduce the heating of an object while machining.
**corundum:** A natural mineral next in hardness to the diamond—one of the hardest minerals used as an abrasive.
**counter shaft:** An interminate shaft between the line shaft and machine from which power is transmitted.
**counter sink:** To cut a flaring depression into which the conical head of a screw will fit so that its face will be flush with the surface.
**counterbore:** To enlarge the end of a round hole to a given depth.
**crocus cloth:** Powdered oxide of iron glued to a cloth backing used for polishing.
**cross cutting:** Cutting across the grain with a saw.
**cross grain:** A wood surface with the fibres crosswise of the stock and not parallel with its length.
**cut:** The amount of material being removed—the division between the teeth of a file or saw.
**cutting oil:** A kind of lubricating oil that is used to reduce friction between the chip and tool in machining. Not designed for use in bearings.
**cylindrical:** Round in shape.

## D

**dado:** A groove, usually crosswise of the grain of wood.
**dead center:** The machine support for revolving work that does not rotate with the work.

**depth gage:** A measuring device to control the depth of a cut as that found in a rabbet plane (woodworking).

**device:** A mechanical object used as an aid in performing a job—a machinist's tools are "devices."

**diagnosing:** Figuring out how a job can best be done.

**die:** 1. Hollow, internally threaded screw-cutting tool, as for forming threads on bolts, etc. 2. One of a pair of cutting or shaping tools which operate by being pressed together. 3. A device used for the exact duplication of many parts.

**die casting:** 1. Method of producing superior castings in permanent molds, the mold being generally of metal and in two pieces. 2. A casting so made; it may be metal or plastic.

**die stock:** The handle that holds the hand-threading die—the supply of material used to make dies.

**dig in:** Spring in the tool or work causing an excess of material to be removed.

**divider:** A tool having two sharp pointed legs used for laying out circles and "stepping off" spaces.

**dog:** A device used to make the object being machined revolve between centers.

**dovetailing:** Making an interlocking joint in wood to eliminate the need of nails.

**dowel pin:** A pin fitting into a hole in an abutting piece to prevent motion or slipping, or to ensure accurate location of assembly.

**draftsman:** One who earns his "living" by the making of drawings to exact dimensions—the person who is usually blamed for the machinist's mistakes and vice versa.

**draw:** To relieve the strains which were set up in a piece of steel by hardening.

**draw filing:** Filing with the file held at right angles to the direction of the stroke.

**draw plate:** The plate on which dies are supported in wire and tube drawing operations.

**drawing holes over:** Shifting the drill in the desired direction after starting to drill and before the drill has entered the work its full diameter.

**drill rod:** High carbon steel rod of various shapes. Originally used for making carbon drills, round stock made in drill sizes; hence the name.

## E

**eccentric:** Deviating from the center or from the line of a circle.

**emery:** Grains of or powdered corundum—abrasive material used for grinding, buffing and polishing.

**emery wheel:** A grinding wheel in which the abrasive grain consists of emery powder, held by a suitable bonding material.

**engage:** Bringing together — when two or more gears run together they are "engaged" — closing the split or half nuts on the lead screw as in threading with the lathe.

**extension bit:** A wood auger bit with adjustable cutter to increase or diminish its boring size.

**eye:** 1. A loop formed at the end of a steel wire or bolt. 2. A loop forming part of anything, or a hole through anything, to receive a rope, hook, pin, shaft, etc. 3. The hole in the hammer head in which the handle is inserted.

## F

**F. P. M.:** Feet per minute.

**face:** A smooth contact surface.

**facing:** Truing a surface, as the end of a shaft or the "boss" on a casting.

**fall line:** The free end of rope where block and tackle is used.

**false jaw:** A protective piece, usually of soft material, used with a clamping device, soft "jaws" of a vice.

**feather:** Projecting flat key or strip (as on a hub, which slides in a keyway of the shaft).

**feather edge:** An unfinished edge from filing or grinding.

**feeding:** Forcing the tool into the work or vice versa — controlled entry of "stock" into the machine.

**feel:** To obtain knowledge by the sense of touch—knowing an object is smooth or rough.





**ferrule:** 1. A ring or cap, usually of metal, put around a cane, tool handle, or similar object, to strengthen it, or prevent splitting and wearing. 2. The small pulley around which the string of a bow is coiled to rotate it, as in a bow drill.

**fettle:** To clean castings after removal from molds, removing runners and sprues.

**file:** To cut away, sharpen or smooth with a file.

**fillister head:** A screwhead, cylindrical in shape having a convex top.

**fit, free:** Liberal allowance; used for running fits with speeds of 600 r.p.m. or over and journal pressures of 600 lb. per sq. in. or more. Used in dynamos, engines, machine tools, etc.

**fit, loose:** Large allowance; permits considerable freedom of movement between members. Used where accuracy is not essential, as in agricultural and mining machinery.

**fit, medium:** Medium allowance; used for running fits with speeds of less than 600 r.p.m. and with journal pressure of less than 600 lb. per sq. in. Employed for more accurate machine tool and automotive parts.

**fit, snug:** Zero allowance; the closest fit that can be assembled by hand. Should be used under conditions of no perceptible shake and where moving parts are not intended to move freely under load.

**fit, tight:** Small negative allowance so that light pressure is necessary for assembly. It results in more or less permanent assembly. Fits of this type are used for drive fits in thin sections and on long fits in other sections. They are also used for shrink fits on extremely light sections.

**fixed:** Fastened in place—not movable—does not mean repaired.

**flat head:** A screw head having a level surface on top — a wood screw with flat head, draws down flush with wood surface.

**fleam:** Angle of bevel of the edge of a sawtooth with respect to the plane of the blade.

**flexible:** Can be bent, formed or twisted without breaking — not stiff.

**flood:** To completely cover as where a stream of "coolant" is kept flowing over the cutting tool.

**flux:** Any substance applied to surfaces to be joined by soldering or welding, just prior to or during the operation, to clean and free them from oxide, thus promoting their union, as rosin.

**forge:** 1. Forming or fabricating by heating and hammering. 2. A furnace used for heating an object that is to be hammered to shape.

**formula:** A set rule used in obtaining general information, i.e. (Td = Do-P). Td = tap drill; Do = outside diameter; P = pitch of the screw or tap to be used. The material being tapped, the speed of tapping and whether or not a "cutting oil" is used also affect the size of the tap drill.

**fractional screws:** Screws having a body diameter of a fractional size.

**fragile:** Easily broken.

**frame:** That part of a micrometer in which the "anvil" and "barrel" or "sleeve" are "fixed."

**friction:** Resistance to motion. Friction is used in driving devices where slippage is desirable. Oils are used to prevent friction by keeping surfaces separated.

**fulcrum:** A point upon which a lever or force may be applied.

**fuller:** Hand tool for grooving and spreading iron.

## G

**gage:** A fixed tool or device used to check the correctness of the object being made — the action of checking or measuring.

**galvanized:** A rust resistant coating of zinc for sheet metal.

**gear train:** Two or more gears so connected that one drives the others.

**gimlet:** A small boring tool with a screw shaped point.

**glycerine:** A colorless semi-liquid soluble in water or alcohol.

**gouge:** A chisel with a concave or convex shaped cutting edge.

**graduated:** A scale or series of markings to which adjustments or measure can be made.

**graduations:** The divisions of an object used for measuring or weighing.

**grain:** The arrangement of the particles of an object that determine its behavior — coarse grained objects have an open arrangement—the fibres or yearly growth in wood as slash grain or vertical grain.
**grind:** To shape and prepare for sharpening the cutting edge of hand tools.
**grind stone:** A hand or power-driven circular stone for grinding purposes.
**gross:** A definite quantity as 12 dozen.
**gusset:** Bracket or angular piece of iron fastened in an angle to give strength or stiffness.
**guy rod:** A firmly supported rod to which a rope or cable is fastened.

## H

**hacksaw:** A metal cutting saw either hand or power.
**half lap:** A joint made by cutting away a half of each of the two pieces joined.
**hand tools:** Tools that are used exclusively by hand such as the hammer, calipers, etc.
**hand-operated tools:** Tools that are power driven but controlled by hand such as the electric drill, hand miller, etc.
**hard wood:** That wood of a dense hard surface, usually the leaf trees as the oak and hickory.
**harden:** To make an object less soft.
**hardness:** The degree of resistance to forces such as bending, twisting, etc.
**head:** The larger or most important part of an object as the head of a bolt, the head of a hammer, etc.
**heat treat:** To use heat as a medium to obtain the desired degree of hardness or softness in an object.
**heel:** The end of the surface opposite the cutting edge that determines the degree of clearance—that part of a hand saw nearest the handle.
**hermaphrodite:** A term commonly used as a name of a tool having one bent and one straight leg. See "morphidite."
**high speed steel:** A special steel used for cutting tools having a high resistance to heat.
**hitch:** To fasten to with rope or cable.
**horn:** The short lever attached to a control of an aircraft by means of which it is operated; as an aileron horn; a rudder horn.

## I

**indicator:** A checking device used to show or indicate variations in the object being checked.
**insert:** A piece that has been put into another larger piece—as the "inserted" teeth of a milling cutter.
**iron:** Supposed to be the result of cell growth of the earliest known form of bacterial life, found in the earth in the form of oxide mixed with impurities. It is reduced in three principal forms—cast iron, steel and wrought iron.

## J

**jack plane:** A 14-inch plane used to straighten, smooth and fit wood stock to a definite size.
**jig:** Contrivance to hold work and to guide a tool, as a drill, or to form a shield or template.
**jointing:** Cutting the teeth of a saw to an even length.

## K

**kerf:** The saw cut or wood removed by the saw blade when sawing.
**key:** An inserted object used to lock two pieces together so that both rotate together.
**keyseat:** The groove in an object in which the key is fixed.
**keyway:** The groove in an object in which the key moves longitudinally.
**knockout:** A bar or other device used to loosen or remove a piece of work, tool or attachment.
**knurl:** One of a series of small beads pressed into a metal surface to aid in holding—as on a nut or handle.

## L

**lag screw:** A bolt having a square head and threaded like a wood screw.
**land:** That part of a surface between grooves.





**lap:** A process of finishing by irregular motion and the use of abrasive—the device used to hold the abrasive when "lapping."
**layout:** The guide lines drawn on an object to aid in machining, locating or forming.
**lead:** The distance a groove travels longitudinally in one revolution. In a single thread the "lead" and "pitch" are the same; in a double thread the "lead" is equal to twice the "pitch." "Lead," pronounced "led" is an element, a heavy plastic metal.
**lead chromate:** A rust resisting paint pigment for metal.
**leverage:** Force exerted to move an object by the use of some form of lever.
**linseed oil:** An oil obtained from the pressing of flax seed.
**lip:** The sharp cutting edge on the end of a tool.
**live center:** The machine support for revolving work that rotates with the work.
**lock nut:** A nut so constructed that it locks itself when screwed up tight; also a nut screwed down hard upon another to prevent slackening.
**longeron:** A fore and aft member of the framing of an airplane fuselage, usually continuous across a number of points of support.
**longitudinal:** Lengthwise.
**lug:** A projection, usually of rectangular cross section.

## M

**machine:** Any combination of simple mechanical devices used in cutting or forming material—the act of cutting or forming material by the use of a machine.
**machine screw:** A small metal screw having a parallel body whose size is designated by a number, as 10-32, 8-32; 10 and 8 are the sizes and 32 is the number of threads per inch. Called a screw because it is almost always used without a nut.
**machinist:** A person who earns his living in some activity of the machine trade—one who has spent enough time in the machine trade to be able to understand, set up, operate and produce work to specifications on any of the basic machines.
**malleable iron:** A form of cast iron that has a surface of low carbon content making it less brittle.
**maple (hard):** A dense hardwood, takes a fine finish; used as tool handles and in ship building.
**mar:** An undesirable mark in the surface of an object.
**messed up:** Marred — confused — spoiled.
**metal:** No sharp line can be drawn between the metals and non-metals commonly understood to mean hard fusible material such as gold, silver, iron, copper, tin, etc.
**mike:** A common shortening of "micrometer" — a measuring tool reading in thousandths.
**milled:** Machined on a milling machine.
**miters:** The joining of wood at an angle as in picture frames.
**morphidite:** A tool having one inside caliper leg and one divider leg.
**mortise:** An opening shaped into a wood surface to receive a tenon.

## N

**non-ferrous:** Not containing iron or ferrite.
**normalizing:** Heat treatment used on castings and forgings to improve the structure and grain of steel. The steel is heated to above its critical range, followed by cooling in air. Temperature, time at that temperature, and cooling conditions must be carefully worked out.
**nut:** A block, usually metal, having an inside thread.

## O

**obtuse:** Blunt, not a sharp angle as pertaining to grinding of a wood chisel.
**oil stone:** An abrasive substance on which hand-edge tools can be sharpened.
**opaque:** A non-transparent surface or film—to cover well.
**operation:** A step in a series in doing a job.

**operator:** A person who tends a machine.

**overhang:** Being above and extending beyond.

## P

**pack-harden:** To heat-treat by packing with carbonaceous material. This treatment can be used on tool-steel instruments of delicate cross section because a relatively low temperature is used and because the work is protected, is quenched from the pot, and comes out clean.

**parallel:** Having all parts equally distant.

**peen:** 1. The end opposite the face of a hammer head. It may be rounded or pointed. 2. To stretch, bend or flatten by hammering with a peen.

**perform:** The act of doing.

**pigment:** A substance, generally a metallic oxide, which forms a paint when mixed with a suitable liquid.

**pin:** A straight or tapered, round piece of metal used to hold two or more objects together.

**pinion:** The smaller of a pair of gears that run together.

**pinning:** The scratches or mars in the work surface caused by particles of metal lodged in the teeth of the tool, usually a file.

**pitch:** The distance from a point on one thread to a corresponding point on the next thread measured longitudinally — in a gear, the number of teeth per unit of pitch diameter.

**pits:** Indentations or mars having greater depth than diameter.

**pivot:** The point about which there is action.

**plane:** A hand tool used to surface, straighten and dress wood stock to size.

**plane iron:** The cutting iron of a plane.

**planish:** To toughen and polish by light hammering.

**plate:** A flat surface—a coating on the surface.

**plywood:** A board consisting of a number of thin layers of wood glued together so that the grain of each layer is at right-angles to that of its neighbor.

**polish:** Having the minimum of mars—a reflecting surface.

**portion:** A part of anything.

**power tools:** Tools that are driven by other than hand power.

**precision:** Accuracy—correctness to a fine degree.

**protractor:** A tool used for measuring angles.

**punch:** A non-rotating tool of steel (usually a short rod) variously shaped at one end for cutting.

## R

**R. P. M.:** Revolutions per minute.

**rabbet:** A channel or groove formed in the edge of a board or plank.

**rack:** A series of shelves or bins—an endless gear, having teeth parallel.

**radial drill press:** A drill press having a beam, supporting the spindle, that can be swung in a radius.

**radius:** Half the diameter—an outside corner having a curved surface.

**rake:** That part of the tool on which the chip slides—that part ground away on top and/or to the side to obtain the desired cutting edge.

**rasped:** A raking rather than a cutting action.

**ratchet:** A device having notches into which a pawl is engaged to obtain motion in one direction—a regulating device on a carpenter's brace to regulate the action of the sweep.

**raw oil:** Linseed oil in its natural state.

**rawhide:** A hide dressed without tanning.

**ream:** To enlarge a hole with a rotating finishing tool having cutting edges.

**reeve:** To pass, as the end of a rope, through any hole or opening in a block, thimble, cleat, ringbolt, cringle, or the like.

**refine:** To purify—to remove impurities.

**resin:** A resinous or pitchy substance occasionally found in the surface of woods.

**rib:** A strengthening brace in a casting or machine.

**ripping:** Sawing with the grain or lengthwise of the stock.





**rivet:** To spread out the end of a bolt or pin so as to form a kind of head by hammering or pressing —a metal fastening device.

**rottenstone:** A soft stone also called "tripoli" used for buffing.

**rouge:** A red powder consisting of ferric oxide used for polishing where a high degree of finish is desired.

**roughing:** Removing excess material as speedily as possible.

**rounding:** To cause a surface to be curved—to remove a sharp corner leaving a "radius."

**rule:** A measuring device used to find the dimensions of an object—a general directive, as the directions for finding an unknown, a formula in words.

## S

**saddle:** That part of a machine that serves as a means of attaching or supporting other parts.

**safe working strength:** The maximum usable loads that can be applied with safety.

**sand-blast:** To clean metal (for example, castings) by means of sand driven at high speed through a nozzle by compressed air.

**sander:** A machine fitted with a grit covered disk or drum for sanding.

**sandpaper:** A paper treated with an abrasive coating.

**sash:** The glazed section of a window, as upper or lower sash.

**saw set:** A hand tool used for bending or setting sawtooth points for blade clearance.

**scale:** A device used to weigh objects—the oxide formed on metal caused by extensive heating.

**scarp:** To cut to a steep slope.

**scraping:** Removing a small amount of metal by moving a sharp-edged tool over the surface.

**screw:** A fastening device that holds by means of some type of thread.

**scriber:** A sharp pointed pencil-like instrument used for making marks on metal.

**sensitive:** Easily controlled, requiring only light force to operate.

**set:** To place or lock in position.

**setting up:** To assemble parts—putting together the holding devices, work and tools in or on a machine in preparation for machining.

**shank:** That part of a tool used to hold or drive.

**shaper:** A machine tool having a reciprocating tool head. It is used for shaping metal.

**shear:** To cut sheet or bar metal with shears or similar instrument.

**sheave:** Pulley used in a tackle block.

**sherardize:** To coat objects with zinc by placing them in a drum with zinc powder, and heating to 575°-850° F. The zinc vapor forms a surface coating of zinc.

**shim:** A thin spacer of metal used in making adjustments.

**silica:** Used as pigment for interior paints, obtained from quartz.

**simultaneous:** At the same time.

**sizing:** Bringing objects to a definite dimension.

**sleeve:** A long, bushing-like part used to form a connection between two parts, may be straight or tapered.

**slot:** A narrow groove.

**snagging:** Rough grinding by hand.

**snatch block:** A single block having an opening in one cheek to receive a rope, and usually having a swivel-hook.

**soft hammer:** A hammer of soft material used to prevent marring.

**spar:** One of the main lateral members of the wing of an airplane, usually of wood or tubular steel. They carry the ribs. Also, occasionally, a longeron.

**special:** Uncommon—not standard—different from the generally accepted.

**speed:** Cutting speed—the amount of work passing the tool in feet per minute, measured on the surface of the work — machine speed — number of revolutions per minute.

**sperm oil:** Oil obtained from the sperm whale.

**spin:** To shape sheet metal by pressure as it revolves in a spinning lathe.

**spindle:** Live spindle—the revolving shaft in a machine that drives the work or tool—dead spindle—the shaft in a machine that does not revolve, used as a support for the work or tool.

**splice:** The joining of rope by weaving and interlocking of the strands.

**spline:** A key in the form of a flat strip for insertion in a slot or groove between parts—a keyway for such a key.

**spot-face:** To machine or finish a spot on a surface—as a seat for a nut or bolt head.

**spotting:** To mark a definite place—spot facing—to machine a small, flat surface on a large object.

**spot-weld:** To join two pieces together by welding isolated spots instead of continuous weld. It is done by the heat-resistance method of electric welding and cannot be used on copper or brass.

**spring:** To bend under strain—to return to original position after the bending force is removed.

**spur:** A lead or cutter as found on the point of an auger.

**spur cutter:** A small cutting unit to sever the shaving at the side as on a rabbet plane.

**stabilizer:** A mechanical device to stabilize the motion of an aircraft, such as a gyroscope or a pendulum device.

**stable:** Remaining in position or condition, not easily moved.

**stepping off:** Using a divider or trammel to locate points or distances on a line, by alternate movement of the legs.

**stock:** A stored supply of material—that part of a machine or tool used to hold other parts as a lathe tail stock, a die stock.

**straight peen:** A type of hammer head having the peen parallel with the eye.

**strap:** Flat stock used as a clamping or holding device.

**stroke:** The distance traveled in either direction of a forth and back movement as a piston, the shaper ram, a file or saw.

**structural steel:** Various forms of steel used for building purposes as: large sizes of angle iron, T-iron, I-beam, etc.

**stubby:** Short.

**swage:** To shape metal by holding it against a swage or swage block and striking it with a hammer.

**swage block:** A perforated block of cast iron or steel with grooved sides, used for heading bolts and swaging bars.

**sweat:** To solder metal pieces together by covering two surfaces with solder and then clamping and heating the whole sufficiently to melt the solder.

**sweep:** The diameter of the sweep necessary for the turning of a brace.

**swivel:** To turn about.

## T

**tack-weld:** To fasten two pieces together by welding small spots at intervals to hold the position while the welding is being done.

**tang:** That part of a file that is put into the handle—that short, flat end on the tapered shank of a drill.

**tap:** A tool used for cutting internal threads.

**tap drill:** A drill used to drill the desired sized hole in which threads are to be cut with a tap.

**temper:** To bring to the desired degree of hardness.

**template:** A thin pattern used for laying out profiles, locating holes, etc.

**tenon:** A shaped protruding end formed in wood framing, to fit into a mortise.

**tension:** The force exerted on an object by stretching.

**texture:** The arrangement of the parts of a body with relation to each other.

**thimble:** An additional surface or lining.

**thinner:** A substance, such as turpentine or petroleum spirits, which is added to a mixed paint in order to thin it to the desired consistency.

**thinning:** Reducing the width.

**throat:** The gullet or junction at the base of the saw tooth.

**thumb-screw:** A screw with flattened head for easy turning with thumb and forefinger.

**tip:** The extreme point or end—to tilt.

**tolerance:** Permissible variations in the dimensions of machine work.

**tongue:** The smaller part of the steel square.

**tool:** Any device used to obtain mechanical advantage, as a file, saw, lever, etc.





**tool maker:** A machinist who specializes in the making of drills, reamers, taps, and other cutting tools.

**tool steel:** Steel containing enough carbon to permit hardening.

**torque:** Twisting force set up in or by a revolving shaft.

**toughness:** The ability to resist forces without breaking.

**trial cut:** The cut taken to determine if calculations and setup will give the desired result.

**tubing:** A form of pipe.

**tumble:** To whirl in a revolving cask as means of cleaning and polishing small castings and forgings by friction. Sometimes additional polishing agents such as balls, sawdust, scraps, etc., are added.

**turning:** To machine in cylindrical form.

**turpentine:** A liquid distilled from the sap or wood of pine trees.

**twist drill:** A drill that has been twisted to form the grooves, in a spiral—a term used to describe all metal cutting drills having spiral grooves.

**type:** Of a general form or character common to several—of a kind.

## U

**universal:** Capable of movement in several directions including circular.

**upset:** To increase the cross section of a heated bar of iron by hammering on the end.

## V

**vernier:** A short scale made to slide along a graduated tool and used to obtain a fine measurement—a type of caliper having a sliding jaw and equipped with a vernier.

**vise:** A holding device having a fixed and a movable jaw.

## W

**washer:** A ring of metal or other material used for various purposes, as around a bolt to form a seat for the head or nut. Also used to relieve friction or prevent motion, etc.

**waste:** String-like remnants from the working of cotton, wool and like material used for wiping machines.

**ways:** Parallel guides upon which parts of a machine move.

**web:** A thin section uniting two larger sections—that part of a drill that separates the flutes.

**whetstone:** A fine-grained stone for whetting edge-tools.

**whetting:** To sharpen to fine edge by using an oil stone.

**wing nut:** A nut having two thin, broad projections on opposite sides to make it easily turned by hand.

**work:** A piece of stock that is being machined.

**working edge:** That which is to be used or seen, from which measurements are to be made.

**wrench:** A tool used to exert turning force.

## Z

**zig-zag rule:** A folding measuring tool with spring joints, graduated in inches by sixteenths.

**zinc sulphate:** Colorless crystals that dissolve in water—a neutralizer.

TANK MAINTENANCE MEN PREPARING TO HAUL A BOGGED-DOWN TANK ONTO LEVEL GROUND WHERE IT CAN BE REPAIRED

# Handy Rules and Tables

## RULES RELATIVE TO THE CIRCLE, THE SQUARE, ETC.

**To Find Circumference—**

Multiply diameter by 3.1416
Divide diameter by 0.3183

**To Find Diameter—**

Multiply circumference by 0.3183
Divide circumference by 3.1416

**To Find Radius—**

Multiply circumference by 0.15915
Divide circumference by 6.28318

**To Find Side of an Inscribed Square—**

Multiply diameter by 0.7071
Multiply circumference by 0.2251
Divide circumference by 4.4428

**To Find Side of Square of Equal Area—**

Multiply diameter by 0.8862
Multiply circumference by 0.2821
Divide diameter by 1.1284
Divide circumference by 3.545

**Square—**

A side multiplied by 1.4142 equals diameter of its circumscribing circle.
A side multiplied by 4.443 equals circumference of its circumscribing circle.
A side multiplied by 1.128 equals diameter of a circle equal in area.
A side multiplied by 3.547 equals circumference of a circle equal in area.
Area of square divided by 1.273 equals area of its inscribed circle.

**To Find the Area of a Circle—**

Multiply circumference by one-quarter of the diameter.
Multiply the square of diameter by 0.7854
Multiply the square of circumference by .07958
Multiply the square of ½ diameter by 3.1416

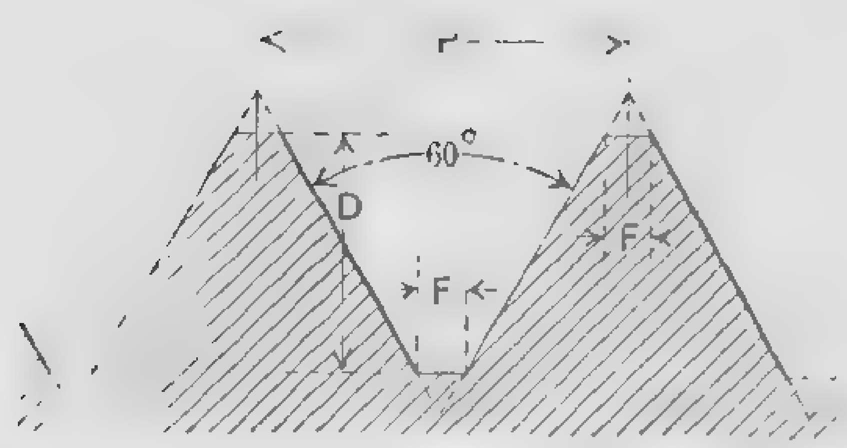
**To Find the Surface Area of a Sphere or Globe—**

Multiply the diameter by the circumference.
Multiply the square of diameter by 3.1416
Multiply four times the square of radius by 3.1416

## DECIMAL EQUIVALENTS OF THE NUMBERS OF TWIST DRILL AND STEEL WIRE GAGE

| No. | Size of No. in Decimals | No. | Size of No. in Decimals | No. | Size of No. in Decimals | No. | Size of No. in Decimals | No. | Size of No. in Decimals |
|---|---|---|---|---|---|---|---|---|---|
| 1 | .2280 | 17 | .1730 | 33 | .1130 | 49 | .0730 | 65 | .0350 |
| 2 | .2210 | 18 | .1695 | 34 | .1110 | 50 | .0700 | 66 | .0330 |
| 3 | .2130 | 19 | .1660 | 35 | .1100 | 51 | .0670 | 67 | .0320 |
| 4 | .2090 | 20 | .1610 | 36 | .1065 | 52 | .0635 | 68 | .0310 |
| 5 | .2055 | 21 | .1590 | 37 | .1040 | 53 | .0595 | 69 | .0292 |
| 6 | .2040 | 22 | .1570 | 38 | .1015 | 54 | .0550 | 70 | .0280 |
| 7 | .2010 | 23 | .1540 | 39 | .0995 | 55 | .0520 | 71 | .0260 |
| 8 | .1990 | 24 | .1520 | 40 | .0980 | 56 | .0465 | 72 | .0250 |
| 9 | .1960 | 25 | .1495 | 41 | .0960 | 57 | .0430 | 73 | .0240 |
| 10 | .1935 | 26 | .1470 | 42 | .0935 | 58 | .0420 | 74 | .0225 |
| 11 | .1910 | 27 | .1440 | 43 | .0890 | 59 | .0410 | 75 | .0210 |
| 12 | .1890 | 28 | .1405 | 44 | .0860 | 60 | .0400 | 76 | .0200 |
| 13 | .1850 | 29 | .1360 | 45 | .0820 | 61 | .0390 | 77 | .0180 |
| 14 | .1820 | 30 | .1285 | 46 | .0810 | 62 | .0380 | 78 | .0160 |
| 15 | .1800 | 31 | .1200 | 47 | .0785 | 63 | .0370 | 79 | .0145 |
| 16 | .1770 | 32 | .1160 | 48 | .0760 | 64 | .0360 | 80 | .0135 |

# AMERICAN NATIONAL COARSE AND FINE THREAD DIMENSIONS AND TAP DRILL SIZES




$p = \text{pitch} = \dfrac{1}{\text{No. thrd. per in.}}$

$d = \text{depth} = p \times .649519$

$f = \text{flat} = \dfrac{p}{8}$

| Size | Threads per Inch NC | Threads per Inch NF | Threads per Inch NS | Outside Diam. Inches | Pitch Diam. Inches | Root Diam. Inches | Tap Drill Approx. 75% Full Thread | Decimal Equiv. of Tap Drill |
|---|---|---|---|---|---|---|---|---|
| 0 | .... | 80 | .. | .0600 | .0519 | .0438 | 3/64 | .0469 |
| 1 | .... | | 56 | .0730 | .0614 | .0498 | 54 | .0550 |
| 1 | 64 | | .. | .0730 | .0629 | .0527 | 53 | .0595 |
| 1 | .... | 72 | .. | .0730 | .0640 | .0550 | 53 | .0595 |
| 2 | 56 | .. | .. | .0860 | .0744 | .0628 | 50 | .0700 |
| 2 | ...... | 64 | .. | .0860 | .0759 | .0657 | 49 | .0730 |
| 3 | 48 | .. | .. | .0990 | .0855 | .0719 | 47 | .0785 |
| 3 | .... | 56 | .. | .0990 | .0874 | .0758 | 45 | .0820 |
| 4 | .... | .. | 32 | .1120 | .0917 | .0714 | 45 | .0820 |
| 4 | .... | .. | 36 | .1120 | .0940 | .0759 | 44 | .0860 |
| 4 | 40 | .. | .. | .1120 | .0958 | .0795 | 43 | .0890 |
| 4 | .... | 48 | .. | .1120 | .0985 | .0849 | 42 | .0935 |
| 5 | .... | .. | 36 | .1250 | .1070 | .0889 | 40 | .0980 |
| 5 | 40 | .. | .. | .1250 | .1088 | .0925 | 38 | .1015 |
| 5 | .. | 44 | .. | .1250 | .1102 | .0955 | 37 | .1040 |
| 6 | 32 | .. | .. | .1380 | .1177 | .0974 | 35 | .1065 |
| 6 | ... | .. | 36 | .1380 | .1200 | .1019 | 34 | .1110 |
| 6 | ... | 40 | .. | .1380 | .1218 | .1055 | 33 | .1130 |
| 8 | ... | .. | 30 | .1640 | .1423 | .1207 | 30 | .1285 |
| 8 | 32 | .. | .. | .1640 | .1437 | .1234 | 29 | .1360 |
| 8 | .... | 36 | .. | .1640 | .1460 | .1279 | 29 | .1360 |
| 8 | .... | | 40 | .1640 | .1478 | .1315 | 28 | .1405 |
| 10 | 24 | | .. | .1900 | .1629 | .1359 | 25 | .1495 |
| 10 | .... | | 28 | .1900 | .1668 | .1436 | 23 | .1510 |
| 10 | ... | | 30 | .1900 | .1684 | .1467 | 22 | .1570 |
| 10 | .... | 32 | .. | .1900 | .1697 | .1494 | 21 | .1590 |
| 12 | 24 | .. | .. | .2160 | .1889 | .1619 | 16 | .1770 |
| 12 | .... | 28 | .. | .2160 | .1928 | .1696 | 14 | .1820 |
| 12 | .... | .. | 32 | .2160 | .1957 | .1754 | 13 | .1850 |
| 1/4 | 20 | .. | .. | .2500 | .2175 | .1850 | 7 | .2010 |
| 1/4 | .... | 28 | .. | .2500 | .2268 | .2036 | 3 | .2130 |
| 5/16 | 18 | .. | .. | .3125 | .2764 | .2403 | F | .2570 |
| 5/16 | .... | 24 | .. | .3125 | .2854 | .2584 | I | .2720 |
| 3/8 | 16 | .. | .. | .3750 | .3344 | .2938 | 5/16 | .3125 |
| 3/8 | .... | 24 | .. | .3750 | .3479 | .3209 | Q | .3320 |
| 7/16 | 14 | .. | .. | .4375 | .3911 | .3447 | U | .3680 |
| 7/16 | .... | 20 | .. | .4375 | .4050 | .3726 | 25/64 | .3906 |
| 1/2 | 13 | .. | .. | .5000 | .4500 | .4001 | 27/64 | .4219 |
| 1/2 | .... | 20 | .. | .5000 | .4675 | .4351 | 29/64 | .4531 |
| 9/16 | 12 | .. | .. | .5625 | .5084 | .4542 | 31/64 | .4844 |
| 9/16 | .... | 18 | .. | .5625 | .5264 | .4903 | 33/64 | .5156 |
| 5/8 | 11 | .. | .. | .6250 | .5660 | .5069 | 17/32 | .5312 |
| 5/8 | ... | 18 | .. | .6250 | .5889 | .5528 | 37/64 | .5781 |
| 3/4 | 10 | .. | .. | .7500 | .6850 | .6201 | 21/32 | .6562 |
| 3/4 | ... | 16 | .. | .7500 | .7094 | .6688 | 11/16 | .6875 |
| 7/8 | 9 | .. | .. | .8750 | .8028 | .7307 | 49/64 | .7656 |
| 7/8 | ... | 14 | .. | .8750 | .8286 | .7822 | 13/16 | .8125 |
| 7/8 | .... | .. | 18 | .8750 | .8389 | .8028 | 53/64 | .8281 |
| 1 | 8 | .. | .. | 1.0000 | .9188 | .8376 | 7/8 | .8750 |
| 1 | .... | 14 | .. | 1.0000 | .9536 | .9072 | 15/16 | .9375 |
| 1 1/8 | 7 | .. | .. | 1.1250 | 1.0322 | .9394 | 63/64 | .9844 |
| 1 1/8 | .... | 12 | .. | 1.1250 | 1.0709 | 1.0168 | 1 3/64 | 1.0469 |
| 1 1/4 | 7 | .. | .. | 1.2500 | 1.1572 | 1.0644 | 1 7/64 | 1.1094 |
| 1 1/4 | .... | 12 | .. | 1.2500 | 1.1959 | 1.1418 | 1 11/64 | 1.1719 |
| 1 3/8 | 6 | .. | .. | 1.3750 | 1.2667 | 1.1585 | 1 7/32 | 1.2187 |
| 1 3/8 | .... | 12 | .. | 1.3750 | 1.3209 | 1.2668 | 1 19/64 | 1.2969 |
| 1 1/2 | 6 | .. | .. | 1.5000 | 1.3917 | 1.2835 | 1 11/32 | 1.3437 |
| 1 1/2 | .... | 12 | .. | 1.5000 | 1.4459 | 1.3918 | 1 27/64 | 1.4219 |
| 1 3/4 | 5 | .. | .. | 1.7500 | 1.6201 | 1.4902 | 1 9/16 | 1.5625 |
| 2 | 4 1/2 | .. | .. | 2.0000 | 1.8557 | 1.7113 | 1 25/32 | 1.7812 |
| 2 1/4 | 4 1/2 | .. | .. | 2.2500 | 2.1057 | 1.9613 | 2 1/32 | 2.0313 |
| 2 1/2 | 4 | .. | .. | 2.5000 | 2.3376 | 2.1752 | 2 1/4 | 2.2500 |
| 2 3/4 | 4 | .. | .. | 2.7500 | 2.5876 | 2.4252 | 2 1/2 | 2.5000 |
| 3 | 4 | .. | .. | 3.0000 | 2.8376 | 2.6752 | 2 3/4 | 2.7500 |
| 3 1/4 | 4 | .. | .. | 3.2500 | 3.0876 | 2.9252 | 3 | 3.0000 |
| 3 1/2 | 4 | .. | .. | 3.5000 | 3.3376 | 3.1752 | 3 1/4 | 3.2500 |
| 3 3/4 | 4 | .. | .. | 3.7500 | 3.5876 | 3.4252 | 3 1/2 | 3.5000 |
| 4 | 4 | .. | .. | 4.0000 | 3.3786 | 3.6752 | 3 3/4 | 3.7500 |



# TABLE OF CUTTING SPEEDS FOR LATHE WORK, DRILLS, AND MILLING CUTTERS

| Diam Inches | Feet per Minute 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 | 70 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Revolutions per Minute | | | | | | | | | | |
| 1/16 | 917. | 1223. | 1528. | 1834. | 2140. | 2445. | 2751. | 3057. | 3668. | 4280. | 4891 |
| 1/8 | 459. | 611. | 764. | 917. | 1070. | 1222. | 1375. | 1528. | 1834. | 2139. | 2445 |
| 3/16 | 306. | 408 | 509 | 611 | 713 | 815. | 917. | 1019. | 1222. | 1426. | 1630 |
| 1/4 | 229. | 306. | 382 | 458. | 535. | 611 | 688 | 764. | 917. | 1070. | 1222 |
| 5/16 | 183. | 245 | 306 | 367 | 428. | 489. | 550. | 611. | 733. | 856. | 978 |
| 3/8 | 153. | 204. | 255. | 306. | 357. | 408. | 458. | 509. | 611. | 713. | 815 |
| 7/16 | 131. | 175. | 218. | 262. | 306. | 349. | 393. | 437. | 524 | 611. | 699 |
| 1/2 | 115. | 153. | 191. | 229. | 268. | 306. | 344. | 382. | 459 | 535. | 611 |
| 5/8 | 91.8 | 123. | 153. | 184. | 214. | 245. | 276. | 306. | 367. | 428. | 489 |
| 3/4 | 76.3 | 102. | 127. | 153. | 178. | 203. | 229. | 254. | 306 | 357. | 408 |
| 7/8 | 65.5 | 87.3 | 109. | 131. | 153. | 175. | 196. | 219. | 262. | 306. | 349 |
| 1 | 57.3 | 76.4 | 95.5 | 115. | 134. | 153. | 172. | 191. | 229. | 267. | 306 |
| 1 1/8 | 51.0 | 68.0 | 85.0 | 102. | 119. | 136. | 153. | 170. | 204 | 238. | 272 |
| 1 1/4 | 45.8 | 61.2 | 76.3 | 91.8 | 107. | 123. | 137. | 153. | 183. | 214. | 245 |
| 1 3/8 | 41.7 | 55.6 | 69.5 | 83.3 | 97.2 | 111. | 125. | 139. | 167. | 195. | 222 |
| 1 1/2 | 38.2 | 50.8 | 63.7 | 76.3 | 89.2 | 102. | 115. | 127. | 153. | 178. | 204 |
| 1 5/8 | 35.0 | 47.0 | 58.8 | 70.5 | 82.2 | 93.9 | 106. | 117. | 141. | 165. | 188 |
| 1 3/4 | 32.7 | 43.6 | 54.5 | 65.5 | 76.4 | 87.3 | 98.2 | 109. | 131. | 153. | 175 |
| 1 7/8 | 30.6 | 40.7 | 50.9 | 61.1 | 71.3 | 81.5 | 91.9 | 102. | 122. | 143. | 163 |
| 2 | 28.7 | 38.2 | 47.8 | 57.3 | 66.9 | 76.4 | 86.0 | 95.5 | 115. | 134. | 153 |
| 2 1/4 | 25.4 | 34.0 | 42.4 | 51.0 | 59.4 | 68.0 | 76.2 | 85.0 | 102. | 119. | 136 |
| 2 1/2 | 22.9 | 30.6 | 38.2 | 45.8 | 53.5 | 61.2 | 68.8 | 76.3 | 91.7 | 107. | 122 |
| 2 3/4 | 20.8 | 27.8 | 34.7 | 41.7 | 48.6 | 55.6 | 62.5 | 69.5 | 83.4 | 97.2 | 111 |
| 3 | 19.1 | 25.5 | 31.8 | 38.2 | 44.6 | 51.0 | 57.3 | 63.7 | 76.4 | 89.1 | 102 |

## AMERICAN NATIONAL PIPE THREAD

### Briggs Standard

### Tap Drill Sizes

| Pipe Size Inches | Threads per Inch | Root Diameter Small End of Pipe and Gage | Tap Drill Size | Tap Drill Decimal Equivalent |
|---|---|---|---|---|
| 1/8 | 27 | .3339 | R | .339 |
| 1/4 | 18 | .4329 | 7/16 | .437 |
| 3/8 | 18 | .5676 | 37/64 | .578 |
| 1/2 | 14 | .7013 | 23/32 | .719 |
| 3/4 | 14 | .9105 | 59/64 | .921 |
| 1 | 11 1/2 | 1.1441 | 1 5/32 | 1.156 |
| 1 1/4 | 11 1/2 | 1.4876 | 1 1/2 | 1.500 |
| 1 1/2 | 11 1/2 | 1.7265 | 1 47/64 | 1.734 |
| 2 | 11 1/2 | 2.1995 | 2 7/32 | 2.218 |
| 2 1/2 | 8 | 2.6195 | 2 5/8 | 2.625 |
| 3 | 8 | 3.2406 | 3 1/4 | 3.250 |
| 3 1/2 | 8 | 3.7375 | 3 3/4 | 3.750 |
| 4 | 8 | 4.2344 | 4 1/4 | 4.250 |

## LETTER SIZES OF DRILLS

| Diameter Inches | Decimals of 1 Inch | Diameter Inches | Decimals of 1 Inch |
|---|---|---|---|
| A 15/64 | .234 | N | .302 |
| B | .238 | O 5/16 | .316 |
| C | .242 | P 21/64 | .323 |
| D | .246 | Q | .332 |
| E 1/4 | .250 | R 11/32 | .339 |
| F | .257 | S | .348 |
| G | .261 | T 23/64 | .358 |
| H 17/64 | .266 | U | .368 |
| I | .272 | V 3/8 | .377 |
| J | .277 | W 25/64 | .386 |
| K 9/32 | .281 | X | .397 |
| L | .290 | Y 13/32 | .404 |
| M 19/64 | .295 | Z | .413 |

## DOUBLE DEPTH OF THREADS

| Threads per Inch N | V Threads DD | Am Nat. Form DD U.S. Std. | Whitworth Standard DD | Threads per Inch N | V Threads DD | Am. Nat. Form DD U.S. Std. | Whitworth Standard DD |
|---|---|---|---|---|---|---|---|
| 2 | .86650 | .64950 | .64000 | 28 | .06185 | .04639 | .04571 |
| 2 1/4 | .77022 | .57733 | .56888 | 30 | .05773 | .04330 | .04266 |
| 2 3/8 | .72960 | .54694 | .53894 | 32 | .05412 | .04059 | .04000 |
| 2 1/2 | .69320 | .51960 | .51200 | 34 | .05097 | .03820 | .03764 |
| 2 5/8 | .66015 | .49485 | .48761 | 36 | .04811 | .03608 | .03555 |
| 2 3/4 | .63019 | .47236 | .46545 | 38 | .04560 | .03418 | .03368 |
| 2 7/8 | .60278 | .45182 | .44521 | 40 | .04330 | .03247 | .03200 |
| 3 | .57733 | .43300 | .42666 | 42 | .04126 | .03093 | .03047 |
| 3 1/4 | .53323 | .39966 | .39384 | 44 | .03936 | .02952 | .03136 |
| 3 1/2 | .49485 | .37114 | .36571 | 46 | .03767 | .02823 | .02782 |
| 4 | .43300 | .32475 | .32000 | 48 | .03608 | .02706 | .02666 |
| 4 1/2 | .38488 | .28869 | .28444 | 50 | .03464 | .02598 | .02560 |
| 5 | .34660 | .25980 | .25600 | 52 | .03332 | .02498 | .02461 |
| 5 1/2 | .31490 | .23618 | .23272 | 54 | .03209 | .02405 | .02370 |
| 6 | .28866 | .21650 | .21333 | 56 | .03093 | .02319 | .02285 |
| 7 | .24742 | .18557 | .18285 | 58 | .02987 | .02239 | .02206 |
| 8 | .21650 | .16237 | .16000 | 60 | .02887 | .02165 | .02133 |
| 9 | .19244 | .14433 | .14222 | 62 | .02795 | .02095 | .02064 |
| 10 | .17320 | .12990 | .12800 | 64 | .02706 | .02029 | .02000 |
| 11 | .15745 | .11809 | .11636 | 66 | .02625 | .01968 | .01939 |
| 11 1/2 | .15069 | .11295 | .11121 | 68 | .02548 | .01910 | .01882 |
| 12 | .14433 | .10825 | .10666 | 70 | .02475 | .01855 | .01728 |
| 13 | .13323 | .09992 | .09846 | 72 | .02407 | .01804 | .01782 |
| 14 | .12357 | .09278 | .09142 | 74 | .02341 | .01752 | .01729 |
| 15 | .11555 | .08660 | .08533 | 76 | .02280 | .01714 | .01673 |
| 16 | .10825 | .08118 | .08000 | 78 | .02221 | .01665 | .01641 |
| 18 | .09622 | .07216 | .07111 | 80 | .02166 | .01623 | .01600 |
| 20 | .08660 | .06495 | .06400 | 82 | .02113 | .01584 | .01560 |
| 22 | .07872 | .05904 | .05818 | 84 | .02063 | .01546 | .01523 |
| 24 | .07216 | .05412 | .05333 | 86 | .02015 | .01510 | .01476 |
| 26 | .06661 | .04996 | .04923 | 88 | .01957 | .01476 | .01454 |
| 27 | .06418 | .04811 | .04740 | 90 | .01925 | .01443 | .01422 |

$DD=\frac{1.733}{N}$ For V Thread $\qquad DD=\frac{1.299}{N}$ For Amer. Nat. Form, U. S. Std.

$DD=\frac{1.28}{N}$ For Whitworth Standard

## TAP DRILL SIZES—75% Depth of Thread

A bolt inserted in an ordinary nut, which has only one-half of a full depth of thread, will break before stripping the thread. Also a full depth of thread, while very difficult to obtain, is only about 5% stronger than a 75% depth.

These tables give the exact size of the hole, expressed in decimals, that will produce a 75% depth of thread, and also the nearest regular stock drill to this size. Holes produced by these drills are considered close enough for any commercial tapping.

$$\text{Diameter of Tap, Minus } \frac{.974}{\text{No. threads per Inch}} = \text{Diameter of Holes}$$

### Tap Drill Sizes—75% Depth Thread—Machine Screw Threads

| Tap Size | Threads per Inch | Diameter Hole | Drill | Tap Size | Threads per Inch | Diameter Hole | Drill |
|---|---|---|---|---|---|---|---|
| 0 | *80 | .048 | 3/64 | 10 | 32 | .160 | 21 |
| 1 | *72 | .060 | 53 | 10 | *30 | .158 | 22 |
| 1 | 64 | .058 | 53 | 10 | 24 | .149 | 25 |
| 2 | *64 | .071 | 50 | 12 | *28 | .181 | 14 |
| 2 | 56 | .069 | 50 | 12 | 24 | .175 | 16 |
| 3 | *56 | .082 | 45 | 14 | *24 | .201 | 7 |
| 3 | 48 | .079 | 47 | 14 | 20 | .193 | 10 |
| 4 | *48 | .092 | 42 | 16 | *22 | .224 | 2 |
| 4 | 40 | .088 | 43 | 16 | 20 | .219 | 7/32 |
| 4 | 36 | .085 | 44 | 16 | 18 | .214 | 3 |
| 5 | *44 | .103 | 37 | 18 | *20 | .245 | D |
| 5 | 40 | .101 | 38 | 18 | 18 | .240 | B |
| 5 | 36 | .098 | 40 | 20 | *20 | .271 | I |
| 6 | *40 | .114 | 33 | 20 | 18 | .266 | 17/64 |
| 6 | 36 | .111 | 34 | 22 | *18 | .292 | L |
| 6 | 32 | .108 | 36 | 22 | 16 | .285 | 9/32 |
| 7 | *36 | .124 | 1/8 | 24 | 18 | .318 | O |
| 7 | 32 | .121 | 31 | 24 | *16 | .311 | 5/16 |
| 7 | 30 | .119 | 31 | 26 | *16 | .337 | R |
| 8 | *36 | .137 | 29 | 26 | 14 | .328 | 21/64 |
| 8 | 32 | .134 | 29 | 28 | 16 | .363 | 23/64 |
| 8 | 30 | .132 | 30 | 28 | *14 | .354 | T |
| 9 | *32 | .147 | 26 | 30 | 16 | .389 | 25/64 |
| 9 | 30 | .145 | 27 | 30 | *14 | .380 | V |
| 9 | 24 | .136 | 29 | | | | |

*A. S. M. E. Standard



## MORSE STANDARD TAPERS

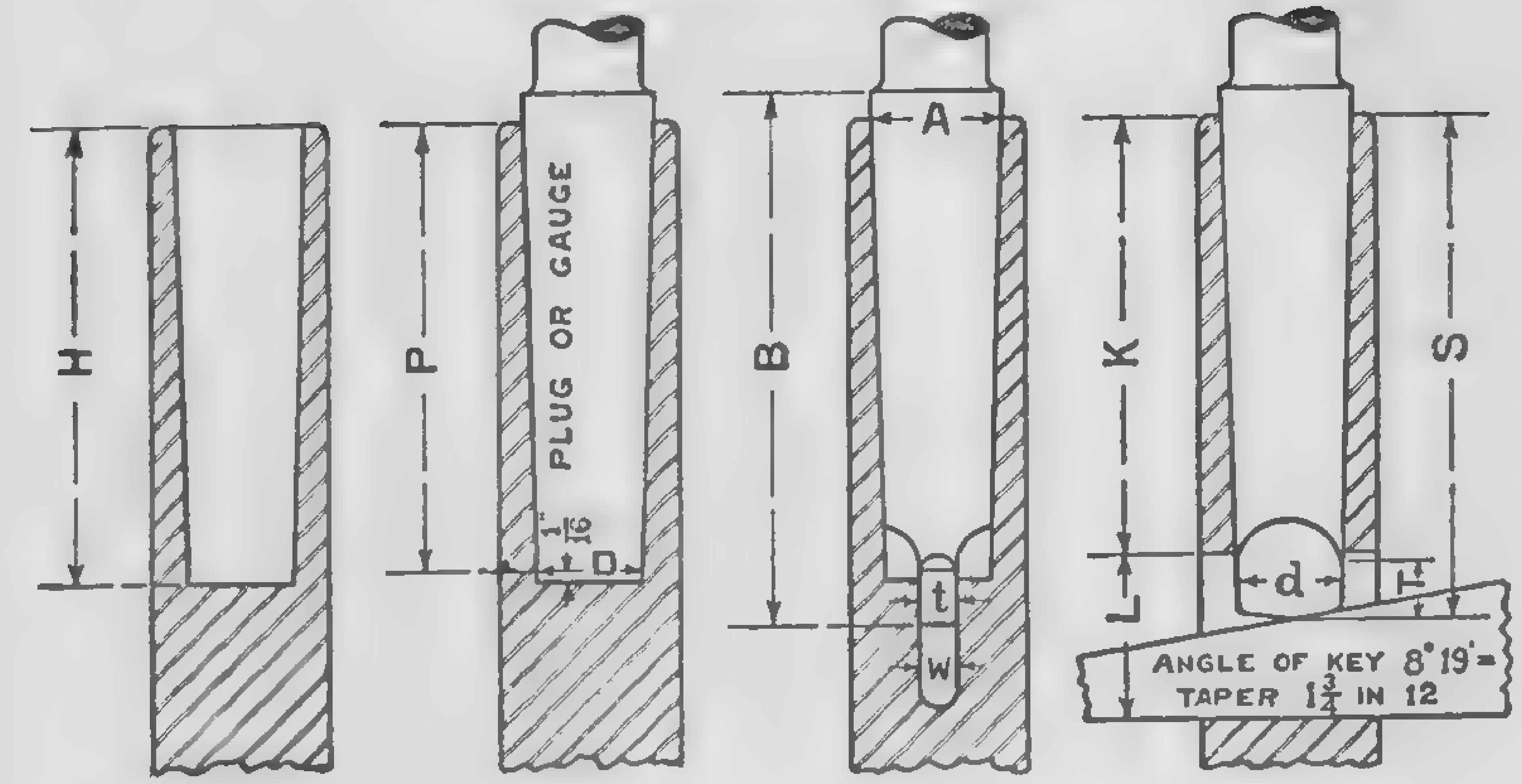



Chart Showing Principal Dimensions of Morse Standard Tapers Which Are Listed in Tabulation Below

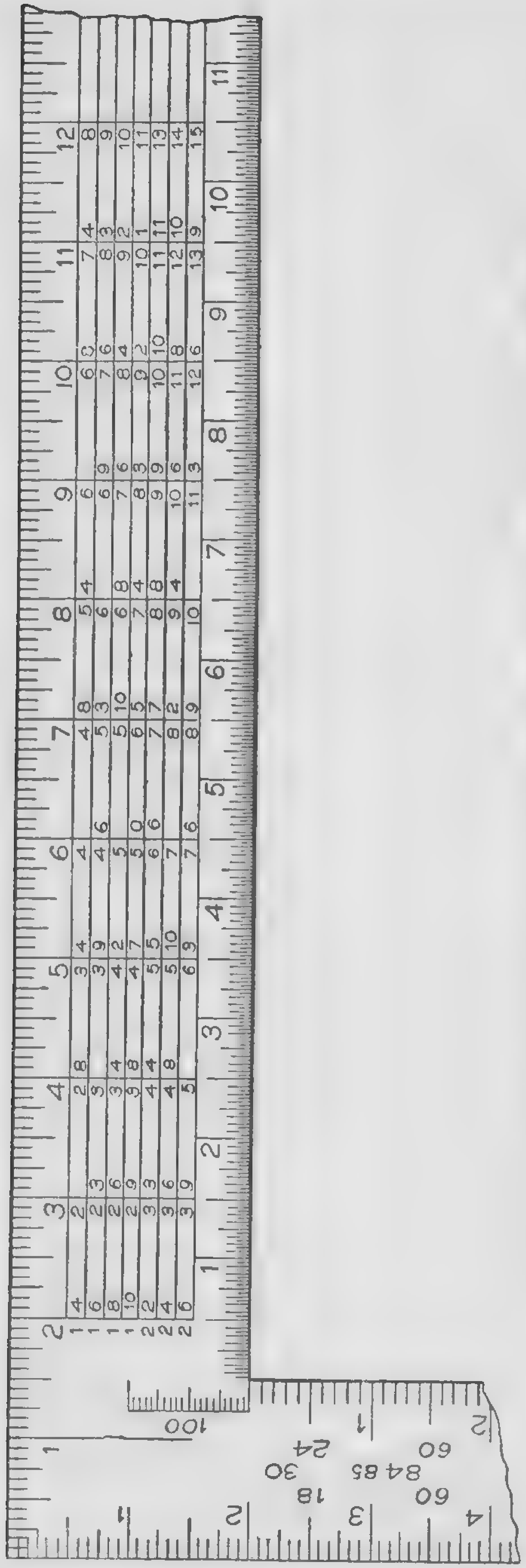
### Dimensions of Morse Standard Tapers
### All Dimensions in Tabulations Below Are in Inches

| Number of Taper | Diam. of Plug at Small End | Diam. at End of Socket | Shank: Whole Length | Shank: Depth | Depth of Hole | Standard Plug Depth | Tongue: Thickness | Tongue: Length | Keyway: Width | Keyway: Length | End of Socket to Keyway | Taper per Foot |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | A | B | S | H | P | t | T | W | L | K | |
| 0 | 0.252 | 0.3561 | 2 11/32 | 2 7/32 | 2 1/32 | 2 | 5/32 | 1/4 | 0.160 | 9/16 | 1 15/16 | .6246 |
| 1 | 0.369 | 0.475 | 2 9/16 | 2 7/16 | 2 3/16 | 2 1/8 | 13/64 | 3/8 | 0.213 | 3/4 | 2 1/16 | .5986 |
| 2 | 0.572 | 0.700 | 3 1/8 | 2 15/16 | 2 5/8 | 2 9/16 | 1/4 | 7/16 | 0.260 | 7/8 | 2 1/2 | .5994 |
| 3 | 0.778 | 0.938 | 3 7/8 | 3 11/16 | 3 1/4 | 3 3/16 | 5/16 | 9/16 | 0.322 | 1 3/16 | 3 1/16 | .6023 |
| 4 | 1.020 | 1.231 | 4 7/8 | 4 5/8 | 4 1/8 | 4 1/16 | 15/32 | 5/8 | 0.478 | 1 1/4 | 3 7/8 | .6233 |
| 5 | 1.475 | 1.748 | 6 1/8 | 5 7/8 | 5 1/4 | 5 3/16 | 5/8 | 3/4 | 0.635 | 1 1/2 | 4 15/16 | .6315 |
| 6 | 2.116 | 2.494 | 8 9/16 | 8 1/4 | 7 3/8 | 7 1/4 | 3/4 | 1 1/8 | 0.760 | 1 3/4 | 7 | .6256 |
| 7 | 2.750 | 3.270 | 11 5/8 | 11 1/4 | 10 1/8 | 10 | 1 1/8 | 1 3/8 | 1.135 | 2 5/8 | 9 1/2 | .6240 |

The figures in the "Taper per Foot" column have been revised to conform with the standard end diameters and lengths.

## BOARD MEASURE

**Calculation.** Lumber is usually reckoned by Board Measure, the unit being a square foot 1 inch thick. Lumber less than 1 inch thick is usually figured as 1 inch. To find the content of squared lumber, multiply length in feet by width and thickness in inches, and divide the product by 12. Or, multiply thickness by width in inches, divide the product by 12 and multiply the result by the length; the result is the Board-Measure Content.



Back of Blade of Steel Square, Showing Essex Board Measure. The complete Standard Steel Square has a *blade* 24 inches long and 2 inches wide, and a *tongue* from 14 to 18 inches long and 1½ inches wide. The *face* of the square shows the manufacturer's name. The reverse side is the *back*. The longer arm is the *blade;* the shorter arm, the *tongue*. One of the important uses of the square, in addition to finding Board Measure, is the facility it affords in finding the *rise* and *run* of the brace. On the *brace rule,* found on the tongue, the fractions denote the rise and run of the brace while the decimals denote the length. For example, a brace of 36 inches run and 36 inches rise, will have a length of 50.91 inches

Shown also on the back of this blade is the Board Measure. Eight parallel lines run the length of the blade, divided at every inch by cross-lines. Under *12*, on the outer edge of the blade, will be found the various lengths of the boards, as 8, 9, 10, 11, 13, etc. For example, take a board 14 feet long and 9 inches wide. To find the contents, look under *12*, and find *14*; follow this space along to the cross-line under *9*, the width of the board; here is found 10 feet 6 inches, denoting the contents of a board 14 feet long and 9 inches wide.



## ILLUSTRATIVE EXAMPLES*

A few examples will show the system for finding the contents of standard sizes in a few seconds and many of them without a moment's hesitation.

**Example:** Find the Board-Measure content of the following sizes:

| Pieces | Size | Length | B.M. |
|---|---|---|---|
| 1 | 2x 8 inches | 30 feet | 40 |
| 1 | 4x10 inches | 18 feet | 60 |
| 1 | 10x10 inches | 36 feet | 300 |
| 1 | 20x20 inches | 60 feet | 2,000 |

## OPERATION

2x8 equals 16 divided by 12 equals 16/12 or 1⅓. When this is multiplied by the length the answer is 40 feet; in other words, add one-third to the length and you have the Board-Measure content.

4x10 equals 40 divided by 12 equals 3⅓ or 10/3. In this instance a cipher is added to the length and when this is divided by three the result is 60 feet Board-Measure content.

10x10 equals 100; this divided by 12 equals 8⅓, or 100/12. It is easier to multiply by 100 and divide by 12 than to multiply by 8⅓, therefore add two ciphers to the length and divide by 12; the result is 300 feet Board-Measure content.

20x20 equals 400, divided by 12 equals 33⅓, or 100/3. All that is necessary is to add two ciphers to the length and divide by 3; the result is 2,000 feet Board-Measure content.

After a short reflection on the above method, it will be apparent to anyone that when this system is used the contents of any ordinary stick of lumber can be figured quickly.

## LUMBER COMPUTATION

The following standard sizes and multiples for same will serve as a basis for practice, and when memorized will benefit those who wish to become rapid in figuring lumber.

### Standard Sizes and Multiples*

| | |
|---|---|
| 1x 3 | Divide lineal feet by 4. |
| 1x 4 | Divide lineal feet by 3. |
| 1x 6 | Divide lineal feet by 2. |
| 1x 8 | Multiply lineal feet by 2 and divide by 3. |
| 1x10 | Multiply lineal feet by 10 and divide by 12. |
| 1x12 | Lineal feet and board measure the same. |
| 2x 3 | Divide lineal feet by 2. |
| 2x 4 | Multiply lineal feet by 2 and divide by 3. |
| 2x 8 | Add to lineal feet ⅓ of amount. |
| 2x10 | Multiply lineal feet by 10 and divide by 6. |
| 2x12 | Multiply lineal feet by 2. |
| 3x 3 | Multiply lineal feet by 3 and divide by 4. |
| 3x 4 | Lineal feet and board measure the same. |

*Courtesy of American Steel and Wire Company

| | |
|---|---|
| 3x 6 | Add to lineal feet ½ the amount. |
| 3x 8 | Multiply lineal feet by 2. |
| 3x10 | Multiply lineal feet by 10 and divide by 4. |
| 3x12 | Multiply lineal feet by 3. |
| 4x 4 | Add to lineal feet ⅓ of amount. |
| 4x 6 | Multiply lineal feet by 2. |
| 4x 8 | Multiply lineal feet by 3 and subtract ⅓ lineal feet from amount. |
| 4x10 | Multiply lineal feet by 10 and divide by 3. |
| 4x12 | Multiply lineal feet by 4. |
| 8x 8 | Multiply lineal feet by 5⅓. |
| 10x10 | Multiply lineal feet by 100 and divide by 12. |
| 12x12 | Multiply lineal feet by 12. |
| 14x14 | Multiply lineal feet by 16⅓. |
| 16x16 | Multiply lineal feet by 21⅓. |
| 18x18 | Multiply lineal feet by 27. |
| 20x20 | Multiply lineal feet by 100 and divide by 3. |
| 22x22 | Multiply lineal feet by 40⅓. |
| 24x24 | Multiply lineal feet by 48. |

**A Variation in Method.*** A handy method for computing Board-Measure content preferred by a number of lumbermen is as follows:

For all 12 ft. lengths multiply width by thickness.
For all 14 ft. lengths multiply width by thickness and add $^1/_6$.
For all 16 ft. lengths multiply width by thickness and add $^1/_3$.
For all 18 ft. lengths multiply width by thickness and add $^1/_2$.
For all 20 ft. lengths multiply width by thickness and add $^2/_3$.
For all 22 ft. lengths multiply width by thickness and add $^5/_6$.
For all 24 ft. lengths multiply width by thickness and double.

Some objection may be taken to the use of $^2/_3$ and $^5/_6$, but often by transposition you can substitute $^1/_6$, $^1/_3$, or $^1/_2$ as in the following:

**Examples:**

10 pcs. 1x18–22 changed to 10 pcs. 1x22–18.
16 pcs. 1x22–20 changed to 20 pcs. 1x22–16.

In the first example instead of multiplying 10x18 and adding $^5/_6$ to the result, multiply 10x22 and add one-half to the result, which will give 330 ft. Board Measure. In the second item instead of multiplying 16x22 and adding ⅔ multiply 20x22 and add ⅓ which gives 586⅔ feet Board Measure.

The above system is very handy when figuring lumber from 12 to 24 feet in length and also where odd widths and thicknesses frequently occur.

*To convert Board Measure to lineal feet,* simply reverse the multiple used to bring lineal feet to Board Measure; in other words, multiply board feet by 12 and divide by thickness and width.

*Courtesy of American Steel and Wire Company



**Example:** How many lineal feet are there in 1,000 feet board measure of 2x8?

*Process:*

$$\begin{array}{r} 1{,}000 \\ \underline{12} \\ 2)\underline{12{,}000} \\ 8)\underline{6{,}000} \\ 750 \text{ lineal feet.} \end{array}$$

Car orders frequently call for a specified amount of sizes containing special lengths. Before proceeding to load it is necessary to find the number of pieces required.

Find the number of pieces in the following order:

1,000 ft. B.M. 2×4–14.
1,000 ft. B.M. 2×4–16.
1,000 ft. B.M. 2×4–20.

Bring the board measure to lineal feet as shown in previous example, then divide the length into lineal feet. The result will be the number of pieces.

*Process:*

$$\begin{array}{r} 1{,}000 \\ \underline{12} \\ 2)\underline{12{,}000} \\ 4)\underline{6{,}000} \\ 1{,}500 \text{ lineal feet.} \end{array}$$

The lineal feet given is now divided by the respective lengths and the following answer is obtained:

| | | |
|---|---|---|
| 107 pcs. 2×4–14 containing | 998 ft. 8 in. | B.M. |
| 94 pcs. 2×4–16 containing | 1,002 ft. 8 in. | B.M. |
| 75 pcs. 2×4–20 containing | 1,000 ft. | B.M. |
| 276 | 3,001 ft. 4 in. | B.M. |

**Tables.** Table 3 shows board measure for various timbers of known length and sectional areas. For a 3 by 4, 2 by 6, or 1 by 12-inch timber look in the column headed 12; for a 2 by 12, 4 by 6, or 3 by 8-inch piece, look in the column headed 24. For lengths not given in the table, take either twice the length and divide by 2, or one-half the length and multiply by 2. Where timbers of the same size abut end to end, it economizes labor in reducing to board measure to take the full length; for this reason the lengths in the table are carried beyond those for single sticks.

**Commercial Sizes of Lumber.** Lumber which is supposed to have been properly seasoned is kept in stock by dealers in the various cities and towns. This lumber is usually furnished in certain standard sizes and is classified, according to the size of the

pieces, into from three to five different types each of which includes lumber of certain standard sizes.

What is known as "dimension stuff," as it comes from the saws, is 2 inches thick and from 4 to 12 inches wide. The narrower sticks are often called **scantlings** and the wider ones **planks.**

**Timbers** are from 4 to 8 inches thick and from 6 to 10 inches wide.

**Common Boards** are 1 inch thick and from 4 to 12 inches wide.

These are the three standard types of rough lumber, and the nominal sizes, but when either the sides or the edges are smoothed up

**Table 3. Board Measure**

| Length in Feet | Sectional Area in Square Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4 ft. in. | 6* ft. in. | 8 ft. in. | 10 ft. in. | 12* ft. in. | 14 ft. in. | 16 ft. in. | 18* ft. in. | 20 ft. in. |
| 6 | 2 0 | 3 0 | 4 0 | 5 0 | 6 0 | 7 0 | 8 0 | 9 0 | 10 0 |
| 8 | 2 8 | 4 0 | 5 4 | 6 8 | 8 0 | 9 4 | 10 8 | 12 0 | 13 4 |
| 10 | 3 4 | 5 0 | 6 8 | 8 4 | 10 0 | 11 8 | 13 4 | 15 0 | 16 8 |
| 12 | 4 0 | 6 0 | 8 0 | 10 0 | 12 0 | 14 0 | 16 0 | 18 0 | 20 0 |
| 14 | 4 8 | 7 0 | 9 4 | 11 8 | 14 0 | 16 4 | 18 8 | 21 0 | 23 4 |
| 16 | 5 4 | 8 0 | 10 8 | 13 4 | 16 0 | 18 8 | 21 4 | 24 0 | 26 8 |
| 18 | 6 0 | 9 0 | 12 0 | 15 0 | 18 0 | 21 0 | 24 0 | 27 0 | 30 0 |
| 20 | 6 8 | 10 0 | 13 4 | 16 8 | 20 0 | 23 4 | 26 8 | 30 0 | 33 4 |
| 22 | 7 4 | 11 0 | 14 8 | 18 4 | 22 0 | 25 8 | 29 4 | 33 0 | 36 8 |
| 24 | 8 0 | 12 0 | 16 0 | 20 0 | 24 0 | 28 0 | 32 0 | 36 0 | 40 0 |
| 26 | 8 8 | 13 0 | 17 4 | 21 8 | 26 0 | 30 4 | 34 8 | 39 0 | 43 4 |
| 28 | 9 4 | 14 0 | 18 8 | 23 4 | 28 0 | 32 8 | 37 4 | 42 0 | 46 8 |
| 30 | 10 0 | 15 0 | 20 0 | 25 0 | 30 0 | 35 0 | 40 0 | 45 0 | 50 0 |
| 32 | 10 8 | 16 0 | 21 4 | 26 8 | 32 0 | 37 4 | 42 8 | 48 0 | 53 4 |
| 34 | 11 4 | 17 0 | 22 8 | 28 4 | 34 0 | 39 8 | 45 4 | 51 0 | 56 8 |
| 36 | 12 0 | 18 0 | 24 0 | 30 0 | 36 0 | 42 0 | 48 0 | 54 0 | 60 0 |
| 38 | 12 8 | 19 0 | 25 4 | 31 8 | 38 0 | 44 4 | 50 8 | 57 0 | 63 4 |
| 40 | 13 4 | 20 0 | 26 8 | 33 4 | 40 0 | 46 8 | 53 4 | 60 0 | 66 8 |
| 42 | 14 0 | 21 0 | 28 0 | 35 0 | 42 0 | 49 0 | 56 0 | 63 0 | 70 0 |

| Length in Feet | Sectional Area in Square Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 24* ft. in. | 28 ft. in. | 30* ft. in. | 32 ft. in. | 35 ft. in. | 36* ft. in. | 40 ft. in. | 42* ft. in. | 48* ft. in. |
| 6 | 12 0 | 14 0 | 15 0 | 16 0 | 17 6 | 18 0 | 20 0 | 21 0 | 24 0 |
| 8 | 16 0 | 18 8 | 20 0 | 21 4 | 23 4 | 24 0 | 26 8 | 28 0 | 32 0 |
| 10 | 20 0 | 23 4 | 25 0 | 26 8 | 29 2 | 30 0 | 33 4 | 35 0 | 40 0 |
| 12 | 24 0 | 28 0 | 30 0 | 32 0 | 35 0 | 36 0 | 40 0 | 42 0 | 48 0 |
| 14 | 28 0 | 32 8 | 35 0 | 37 4 | 40 10 | 42 0 | 46 8 | 49 0 | 56 0 |
| 16 | 32 0 | 37 4 | 40 0 | 42 8 | 46 8 | 48 0 | 53 4 | 56 0 | 64 0 |
| 18 | 36 0 | 42 0 | 45 0 | 48 0 | 52 6 | 54 0 | 60 0 | 63 0 | 72 0 |
| 20 | 40 0 | 46 8 | 50 0 | 53 4 | 58 4 | 60 0 | 66 8 | 70 0 | 80 0 |
| 22 | 44 0 | 51 4 | 55 0 | 58 8 | 64 2 | 66 0 | 73 4 | 77 0 | 88 0 |
| 24 | 48 0 | 56 0 | 60 0 | 64 0 | 70 0 | 72 0 | 80 0 | 84 0 | 96 0 |
| 26 | 52 0 | 60 8 | 65 0 | 69 4 | 75 10 | 78 0 | 86 8 | 91 0 | 104 0 |
| 28 | 56 0 | 65 4 | 70 0 | 74 8 | 81 8 | 84 0 | 93 4 | 98 0 | 112 0 |
| 30 | 60 0 | 70 0 | 75 0 | 80 0 | 87 6 | 90 0 | 100 0 | 105 0 | 120 0 |
| 32 | 64 0 | 74 8 | 80 0 | 85 4 | 93 4 | 96 0 | 106 8 | 112 0 | 128 0 |
| 34 | 68 0 | 79 4 | 85 0 | 90 8 | 99 2 | 102 0 | 113 4 | 119 0 | 136 0 |
| 36 | 72 0 | 84 0 | 90 0 | 96 0 | 105 0 | 108 0 | 120 0 | 126 0 | 144 0 |
| 38 | 76 0 | 88 8 | 95 0 | 101 4 | 110 10 | 114 0 | 126 8 | 133 0 | 152 0 |
| 40 | 80 0 | 93 4 | 100 0 | 106 8 | 116 8 | 120 0 | 133 4 | 140 0 | 160 0 |
| 42 | 84 0 | 98 0 | 105 0 | 112 0 | 122 6 | 126 0 | 140 0 | 147 0 | 168 0 |

*The measurements in these columns come out in even feet.

Courtesy of John Wiley & Sons, New York. Entire Table 3 reproduced from *Kidder-Parker Architects' and Builders' Handbook*, 18th ed.



**Table 3. Board Measure (continued)**

| Length in Feet | Sectional Area in Square Inches | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 56 ft. in. | 60* ft. in. | 64 ft. in. | 72* ft. in. | 80 ft. in. | 84* ft. in. | 96* ft. in. | 100 ft. in. | 112 ft. in. |
| 4 | 18 8 | 20 0 | 21 4 | 24 0 | 26 8 | 28 0 | 32 0 | 33 4 | 37 4 |
| 6 | 28 0 | 30 0 | 32 0 | 36 0 | 40 0 | 42 0 | 48 0 | 50 0 | 56 0 |
| 8 | 37 4 | 40 0 | 42 8 | 48 0 | 53 4 | 56 0 | 64 0 | 66 8 | 74 8 |
| 10 | 46 8 | 50 0 | 53 4 | 60 0 | 66 8 | 70 0 | 80 0 | 83 4 | 93 4 |
| 12 | 56 0 | 60 0 | 64 0 | 72 0 | 80 0 | 84 0 | 96 0 | 100 0 | 112 0 |
| 14 | 65 4 | 70 0 | 74 8 | 84 0 | 93 4 | 98 0 | 112 0 | 116 8 | 130 8 |
| 16 | 74 8 | 80 0 | 85 4 | 96 0 | 106 8 | 112 0 | 128 0 | 133 4 | 149 4 |
| 18 | 84 0 | 90 0 | 96 0 | 108 0 | 120 0 | 126 0 | 144 0 | 150 0 | 168 0 |
| 20 | 93 4 | 100 0 | 106 8 | 120 0 | 133 4 | 140 0 | 160 0 | 166 8 | 186 8 |
| 22 | 102 8 | 110 0 | 117 4 | 132 0 | 146 8 | 154 0 | 176 0 | 183 4 | 205 4 |
| 24 | 112 0 | 120 0 | 128 0 | 144 0 | 160 0 | 168 0 | 192 0 | 200 0 | 224 0 |
| 26 | 121 4 | 130 0 | 138 8 | 156 0 | 173 4 | 182 0 | 208 0 | 216 8 | 242 8 |
| 28 | 130 8 | 140 0 | 149 4 | 168 0 | 186 8 | 196 0 | 224 0 | 233 4 | 261 4 |
| 30 | 140 0 | 150 0 | 160 0 | 180 0 | 200 0 | 210 0 | 240 0 | 250 0 | 280 0 |
| 32 | 149 4 | 160 0 | 170 8 | 192 0 | 213 4 | 224 0 | 256 0 | 266 8 | 298 8 |
| 34 | 158 8 | 170 0 | 181 4 | 204 0 | 226 8 | 238 0 | 272 0 | 283 4 | 317 4 |
| 36 | 168 0 | 180 0 | 192 0 | 216 0 | 240 0 | 252 0 | 288 0 | 300 0 | 336 0 |
| 38 | 177 4 | 190 0 | 202 8 | 228 0 | 253 4 | 266 0 | 304 0 | 316 8 | 354 8 |
| 40 | 186 8 | 200 0 | 213 4 | 240 0 | 266 8 | 280 0 | 320 0 | 333 4 | 373 4 |
| 42 | 196 0 | 210 0 | 224 0 | 252 0 | 280 0 | 294 0 | 336 0 | 350 0 | 392 0 |
| 44 | 205 4 | 220 0 | 234 8 | 264 0 | 293 4 | 308 0 | 352 0 | 366 8 | 410 8 |
| 46 | 214 8 | 230 0 | 245 4 | 276 0 | 306 8 | 322 0 | 368 0 | 383 4 | 429 4 |
| 48 | 224 0 | 240 0 | 256 0 | 288 0 | 320 0 | 336 0 | 384 0 | 400 0 | 448 0 |
| 50 | 233 4 | 250 0 | 266 8 | 300 0 | 333 4 | 350 0 | 400 0 | 416 8 | 466 8 |
| 52 | 242 8 | 260 0 | 277 4 | 312 0 | 346 8 | 364 0 | 416 0 | 433 4 | 485 4 |
| 54 | 252 0 | 270 0 | 288 0 | 324 0 | 360 0 | 378 0 | 432 0 | 450 0 | 504 0 |
| 56 | 261 4 | 280 0 | 298 8 | 336 0 | 373 4 | 392 0 | 448 0 | 466 8 | 522 8 |
| 58 | 270 8 | 290 0 | 309 4 | 348 0 | 386 8 | 406 0 | 464 0 | 483 4 | 541 4 |
| 60 | 280 0 | 300 0 | 320 0 | 360 0 | 400 0 | 420 0 | 480 0 | 500 0 | 560 0 |
| 62 | 289 4 | 310 0 | 330 8 | 372 0 | 413 4 | 434 0 | 496 0 | 516 8 | 578 8 |
| 64 | 298 8 | 320 0 | 341 4 | 384 0 | 426 8 | 448 0 | 512 0 | 533 4 | 597 4 |
| 66 | 308 0 | 330 0 | 352 0 | 396 0 | 440 0 | 462 0 | 528 0 | 550 0 | 616 0 |
| 68 | 317 4 | 340 0 | 362 8 | 408 0 | 453 4 | 476 0 | 544 0 | 566 8 | 634 8 |
| 70 | 326 8 | 350 0 | 373 4 | 420 0 | 466 8 | 490 0 | 560 0 | 583 4 | 653 4 |
| 72 | 336 0 | 360 0 | 384 0 | 432 0 | 480 0 | 504 0 | 576 0 | 600 0 | 672 0 |

| Length in Feet | Size and Sectional Area in Square Inches | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 120* 10x12 ft. in. | 140 10x14 ft. in. | 144* 12x12 ft. in. | 160 10x16 ft. in. | 168* 12x14 ft. in. | 192* 12x16 ft. in. | 196 14x14 ft. in. | 224 14x16 ft. in. |
| 4 | 40 0 | 46 8 | 48 0 | 53 4 | 56 0 | 64 0 | 65 4 | 74 8 |
| 6 | 60 0 | 70 0 | 72 0 | 80 0 | 84 0 | 96 0 | 98 0 | 112 0 |
| 8 | 80 0 | 93 4 | 96 0 | 106 8 | 112 0 | 128 0 | 130 8 | 149 4 |
| 10 | 100 0 | 116 8 | 120 0 | 133 4 | 140 0 | 160 0 | 163 4 | 186 8 |
| 12 | 120 0 | 140 0 | 144 0 | 160 0 | 168 0 | 192 0 | 196 0 | 224 0 |
| 14 | 140 0 | 163 4 | 168 0 | 186 8 | 196 0 | 224 0 | 228 8 | 261 4 |
| 16 | 160 0 | 186 8 | 192 0 | 213 4 | 224 0 | 256 0 | 261 4 | 298 8 |
| 18 | 180 0 | 210 0 | 216 0 | 240 0 | 252 0 | 288 0 | 294 0 | 336 0 |
| 20 | 200 0 | 233 4 | 240 0 | 266 8 | 280 0 | 320 0 | 326 8 | 373 4 |
| 22 | 220 0 | 256 8 | 264 0 | 293 4 | 308 0 | 352 0 | 359 4 | 410 8 |
| 24 | 240 0 | 280 0 | 288 0 | 320 0 | 336 0 | 384 0 | 392 0 | 448 0 |
| 26 | 260 0 | 303 4 | 312 0 | 346 8 | 364 0 | 416 0 | 424 8 | 485 4 |
| 28 | 280 0 | 326 8 | 336 0 | 373 4 | 392 0 | 448 0 | 457 4 | 522 8 |
| 30 | 300 0 | 350 0 | 360 0 | 400 0 | 420 0 | 480 0 | 490 0 | 560 0 |
| 32 | 320 0 | 373 4 | 384 0 | 426 8 | 448 0 | 512 0 | 522 8 | 597 4 |
| 34 | 340 0 | 396 8 | 408 0 | 453 4 | 476 0 | 544 0 | 555 4 | 634 8 |
| 36 | 360 0 | 420 0 | 432 0 | 480 0 | 504 0 | 576 0 | 588 0 | 672 0 |
| 38 | 380 0 | 443 4 | 456 0 | 506 8 | 532 0 | 608 0 | 620 8 | 709 4 |
| 40 | 400 0 | 466 8 | 480 0 | 533 4 | 560 0 | 640 0 | 653 4 | 746 8 |
| 42 | 420 0 | 490 0 | 504 0 | 560 0 | 588 0 | 672 0 | 686 0 | 784 0 |
| 44 | 440 0 | 513 4 | 528 0 | 586 8 | 616 0 | 704 0 | 718 8 | 821 4 |
| 46 | 460 0 | 536 8 | 552 0 | 613 4 | 644 0 | 736 0 | 751 4 | 858 8 |
| 48 | 480 0 | 560 0 | 576 0 | 640 0 | 672 0 | 768 0 | 784 0 | 896 0 |
| 50 | 500 0 | 583 4 | 600 0 | 666 8 | 700 0 | 800 0 | 816 8 | 933 4 |
| 52 | 520 0 | 606 8 | 624 0 | 693 4 | 728 0 | 832 0 | 849 4 | 970 8 |
| 54 | 540 0 | 630 0 | 648 0 | 720 0 | 756 0 | 864 0 | 882 0 | 1008 0 |
| 56 | 560 0 | 653 4 | 672 0 | 746 8 | 784 0 | 896 0 | 914 8 | 1045 4 |
| 58 | 580 0 | 676 8 | 696 0 | 773 4 | 812 0 | 928 0 | 947 4 | 1082 8 |
| 60 | 600 0 | 700 0 | 720 0 | 800 0 | 840 0 | 960 0 | 980 0 | 1120 0 |
| 62 | 620 0 | 723 4 | 744 0 | 826 8 | 868 0 | 992 0 | 1012 8 | 1157 4 |
| 64 | 640 0 | 746 8 | 768 0 | 853 4 | 896 0 | 1024 0 | 1045 4 | 1194 8 |
| 66 | 660 0 | 770 0 | 792 0 | 880 0 | 924 0 | 1056 0 | 1078 0 | 1232 0 |
| 68 | 680 0 | 793 4 | 816 0 | 906 8 | 952 0 | 1088 0 | 1110 8 | 1269 4 |
| 70 | 700 0 | 816 8 | 840 0 | 933 4 | 980 0 | 1120 0 | 1143 4 | 1306 8 |
| 72 | 720 0 | 840 0 | 864 0 | 960 0 | 1008 0 | 1152 0 | 1176 0 | 1344 0 |

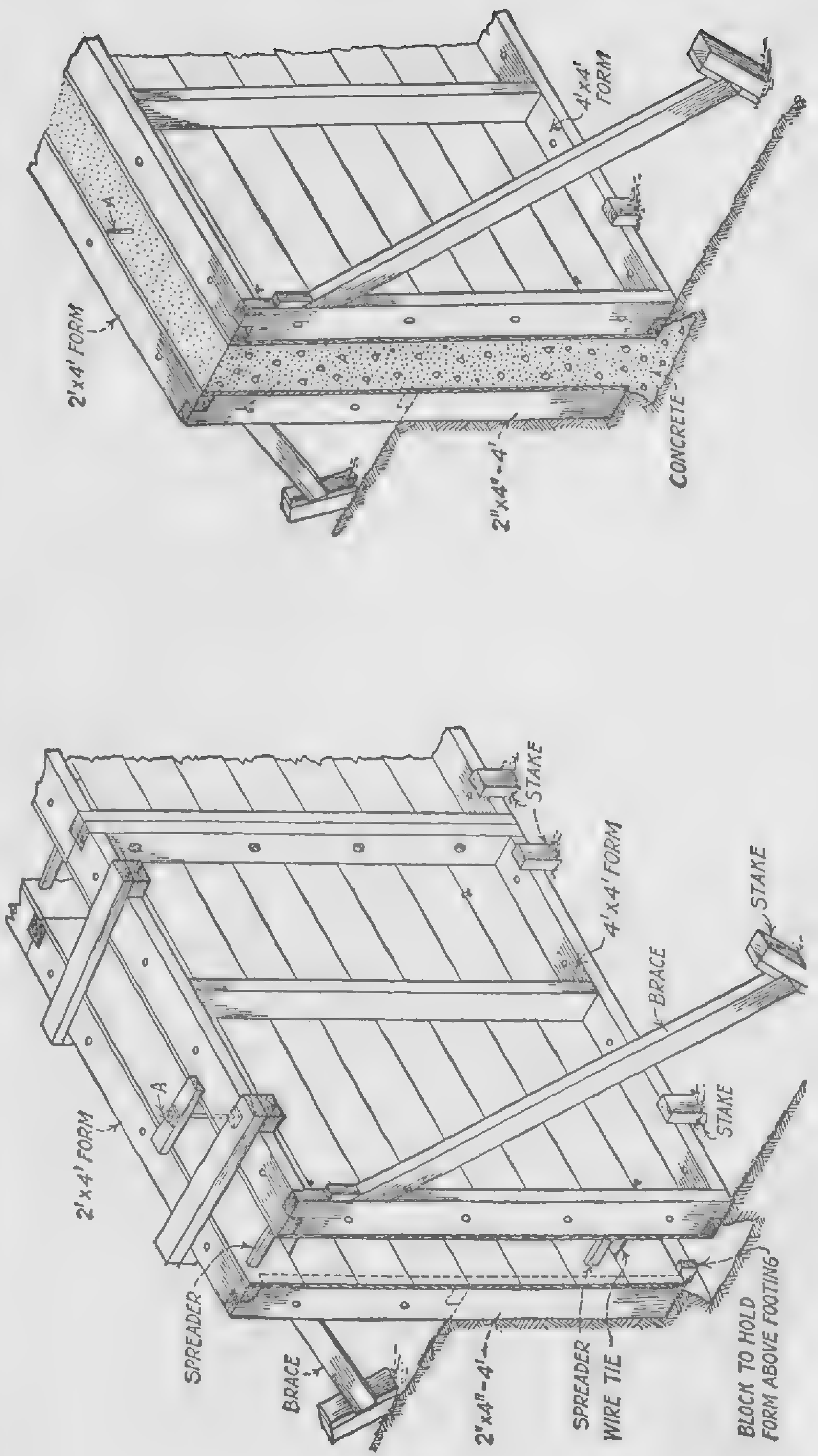
or *dressed* about 1/8 inch is taken off from each side of the thinnest pieces and from 3/8 to 1/2 inch is taken off from the sides or edges of the thickest pieces. This smoothing process is often called *surfacing* and the letters "D" for "dressed" or "S" for "surfaced" are used to show how many sides or edges of a piece are to be dressed or surfaced. Thus D.1.S. or S.1.S. means dressed or surfaced on one side and D.1.E. or S.1.E. means dressed or surfaced on one edge. S.4.S. means surfaced on all four sides or edges while S.1.S.1.E. means surfaced on one side and one edge.

**Table 4. Standard Sizes of Lumber**

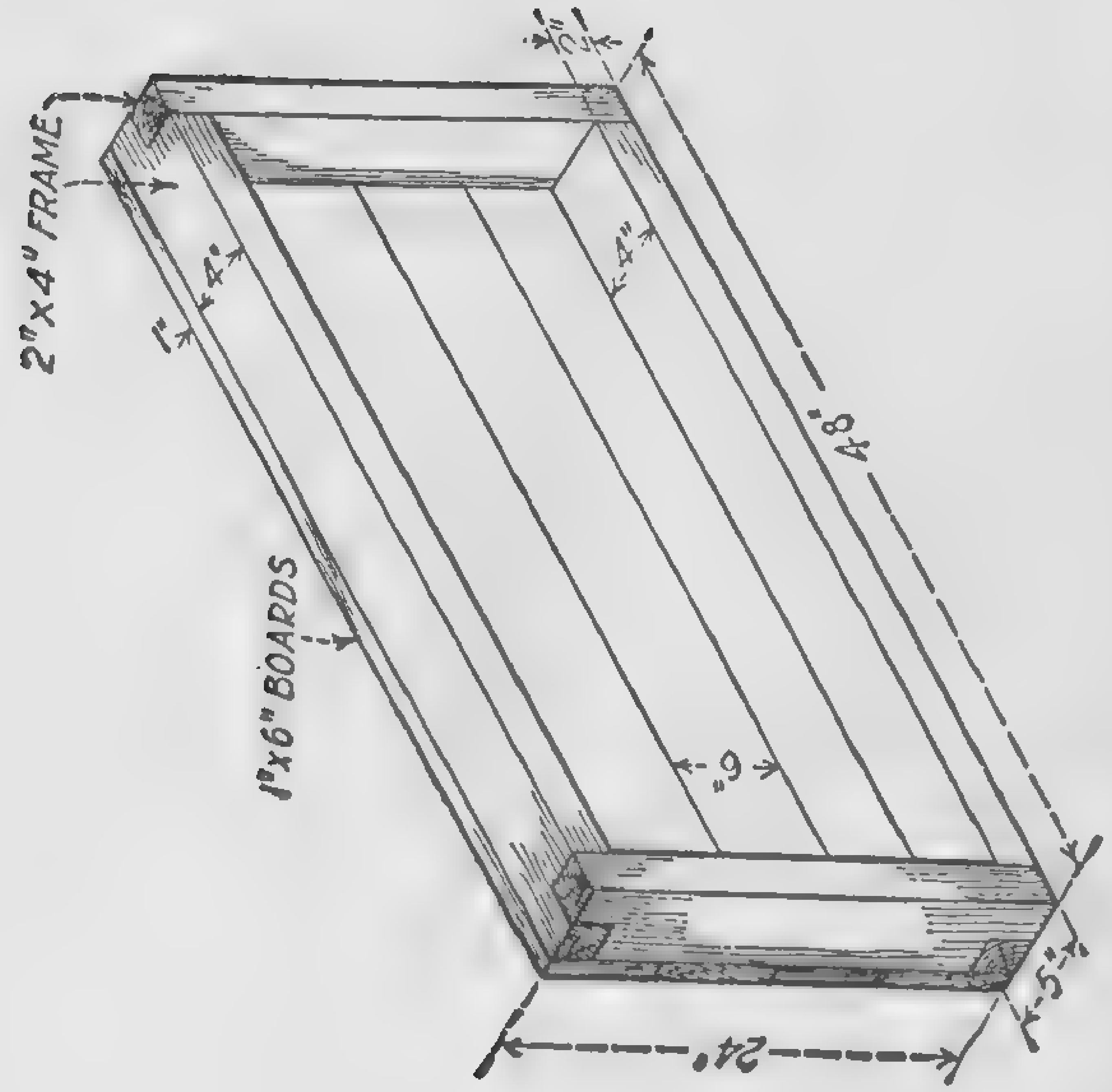
Conforming with the recommendations of the Lumber Industry as set forth in Simplified Practice Recommendations No. 16 published by the United States Department of Commerce.

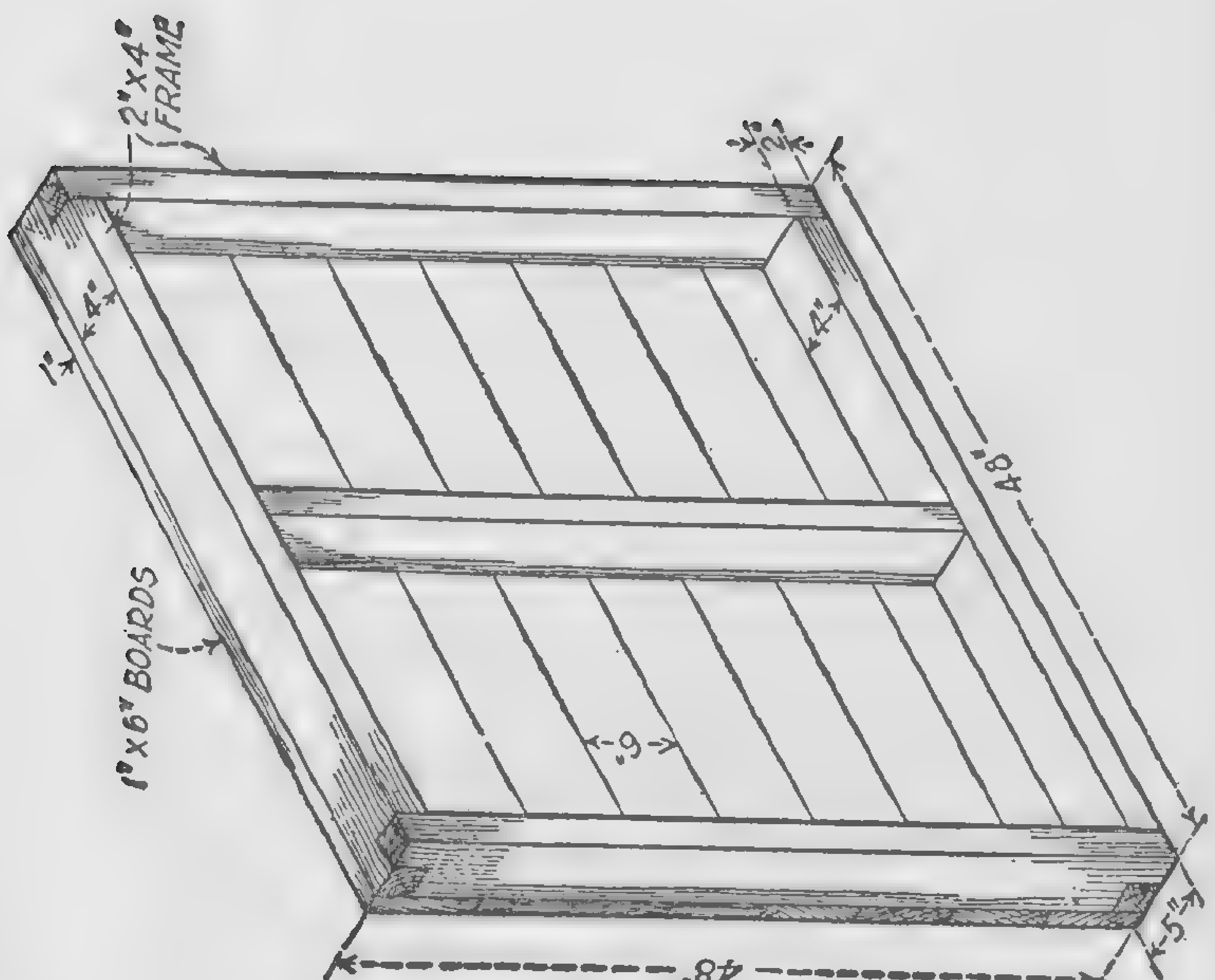
| Type of Lumber | Nominal Size | | Actual Size S4S At Comm. Dry Shp. Wt. | |
|---|---|---|---|---|
| | Thickness Inches | Width Inches | Thickness Inches | Width Inches |
| Dimension | 2 | 4 | 1 5/8 | 3 5/8 |
| | 2 | 6 | 1 5/8 | 5 5/8 |
| | 2 | 8 | 1 5/8 | 7 1/2 |
| | 2 | 10 | 1 5/8 | 9 1/2 |
| | 2 | 12 | 1 5/8 | 11 1/2 |
| Timbers | 4 | 6 | 3 5/8 | 5 1/2 |
| | 4 | 8 | 3 5/8 | 7 1/2 |
| | 4 | 10 | 3 5/8 | 9 1/2 |
| | 6 | 6 | 5 1/2 | 5 1/2 |
| | 6 | 8 | 5 1/2 | 7 1/2 |
| | 6 | 10 | 5 1/2 | 9 1/2 |
| | 8 | 8 | 7 1/2 | 7 1/2 |
| | 8 | 10 | 7 1/2 | 9 1/2 |
| Common Boards | 1 | 4 | 25/32 | 3 5/8 |
| | 1 | 6 | 25/32 | 5 5/8 |
| | 1 | 8 | 25/32 | 7 1/2 |
| | 1 | 10 | 25/32 | 9 1/2 |
| | 1 | 12 | 25/32 | 11 1/2 |
| Shiplap Boards | 1 | 4 | 25/32 | 3 1/8 face |
| | 1 | 6 | 25/32 | 5 1/8 face |
| | 1 | 8 | 25/32 | 7 1/8 face |
| | 1 | 10 | 25/32 | 9 1/8 face |
| | 1 | 12 | 25/32 | 11 1/8 face |
| Tongued and Grooved Boards | 1 | 4 | 25/32 | 3 1/4 face |
| | 1 | 6 | 25/32 | 5 1/4 face |
| | 1 | 8 | 25/32 | 7 1/4 face |
| | 1 | 10 | 25/32 | 9 1/4 face |
| | 1 | 12 | 25/32 | 11 1/4 face |






DETAIL OF WALL FORMS




DETAIL OF UNIT FORMS



## Decimal Equivalents of Fractions of an Inch

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1/64 | 0.015625 | | | | | | 33/64 | 0.515625 |
| | | | | 1/32 | | 0.03125 | | | | | 17/32 | | 0.53125 |
| | | | | | 3/64 | 0.046875 | | | | | | 35/64 | 0.546875 |
| | | | 1/16 | | | 0.0625 | | | | 9/16 | | | 0.5625 |
| | | | | | 5/64 | 0.078125 | | | | | | 37/64 | 0.578125 |
| | | | | 3/32 | | 0.09375 | | | | | 19/32 | | 0.59375 |
| | | | | | 7/64 | 0.109375 | | | | | | 39/64 | 0.609375 |
| | | 1/8 | | | | 0.125 | | | 5/8 | | | | 0.625 |
| | | | | | 9/64 | 0.140625 | | | | | | 41/64 | 0.640625 |
| | | | | 5/32 | | 0.15625 | | | | | 21/32 | | 0.65625 |
| | | | | | 11/64 | 0.171875 | | | | | | 43/64 | 0.671875 |
| | | | 3/16 | | | 0.1875 | | | | 11/16 | | | 0.6875 |
| | | | | | 13/64 | 0.203125 | | | | | | 45/64 | 0.703125 |
| | | | | 7/32 | | 0.21875 | | | | | 23/32 | | 0.71875 |
| | | | | | 15/64 | 0.234375 | | | | | | 47/64 | 0.734375 |
| | 1/4 | | | | | 0.250 | | 3/4 | | | | | 0.750 |
| | | | | | 17/64 | 0.265625 | | | | | | 49/64 | 0.765625 |
| | | | | 9/32 | | 0.28125 | | | | | 25/32 | | 0.78125 |
| | | | | | 19/64 | 0.296875 | | | | | | 51/64 | 0.796875 |
| | | | 5/16 | | | 0.3125 | | | | 13/16 | | | 0.8125 |
| | | | | | 21/64 | 0.328125 | | | | | | 53/64 | 0.828125 |
| | | | | 11/32 | | 0.34375 | | | | | 27/32 | | 0.84375 |
| | | | | | 23/64 | 0.359375 | | | | | | 55/64 | 0.859375 |
| | | 3/8 | | | | 0.375 | | | 7/8 | | | | 0.875 |
| | | | | | 25/64 | 0.390625 | | | | | | 57/64 | 0.890625 |
| | | | | 13/32 | | 0.40625 | | | | | 29/32 | | 0.90625 |
| | | | | | 27/64 | 0.421875 | | | | | | 59/64 | 0.921875 |
| | | | 7/16 | | | 0.4375 | | | | 15/16 | | | 0.9375 |
| | | | | | 29/64 | 0.453125 | | | | | | 61/64 | 0.953125 |
| | | | | 15/32 | | 0.46875 | | | | | 31/32 | | 0.96875 |
| | | | | | 31/64 | 0.484375 | | | | | | 63/64 | 0.984375 |
| 1/2 | | | | | | 0.500 | 1 | | | | | | 1. |

M-4 MEDIUM TANK, COMPLETE WITH 75 MILLIMETER GUN, TURRET WHICH TURNS 360°, AND MACHINE GUNS

*Photo by U. S. Army Signal Corps*



# INDEX

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